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# ZOOLOGICA

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ARCTURUS OCEANOGRAPHIC EXPEDITION

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# THE ARCTURUS OCEANOGRAPHIC EXPEDITION\*

BY WILLIAM BEEBE

(Fig. 1 and Plates A. B. C.)

## OUTLINE

- I. INTRODUCTION.
- II. LIST OF STATIONS WITH ACCOMPANYING DATA
- III. CHART OF TEMPERATURES OF PACIFIC STATIONS
- IV. SEA-WATER SALINITY AT STATIONS.
- V. RÉSUMÉ OF STATION AND HAUL RESULTS
- VI. PACIFIC DEPTH PLANKTON HAULS.
- VII. RELATIVE ABUNDANCE OF FIFTY-SEVEN GROUPS OF INVERTEBRATES IN PACIFIC SURFACE HAULS.
- VIII. RELATIVE ABUNDANCE OF SIX MAJOR GROUPS OF INVERTEBRATES IN FORTY-SEVEN SURFACE HAULS IN THE PACIFIC.

## I. INTRODUCTION

The Arcturus Oceanographic Expedition, the ninth expedition of the New York Zoological Society, sailed from Brooklyn on February 11th, 1925, and returned to New York on July 30th. In the interval we steamed a distance of over 13,600 miles, touching at Norfolk, Bermuda, Panama, Cocos Island and the Galapagos. We brought back 11,000 feet of first rate motion picture film, besides a great many colored plates and photographs. We established one hundred and thirteen stations, made hundreds of hauls with nets and dredges, threw overboard two thousand drift bottles containing the usual data.

The avowed objects of the expedition were the investigation of the Sargasso Sea and the mid and deep sea life beneath it, and the study of the Humboldt Current. Owing to continual storms the former was in such a disintegrated condition that I soon decided to postpone detailed study until a more favorable time. In the Pacific, to our surprise, we found that there was absolutely no trace of the Humboldt Current about the Galápagos. The inexplicable absence of this great, cold, Antarctic current was amply compensated for by the equally unexpected presence of unusual natural events.

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\* Contribution, New York Zoological Society Department of Tropical Research, No. 246.



Fig. 1. S. Y. Arcturus.

Among the high lights of the expedition may be mentioned the great volcanic eruption on Albemarle Island, the albatross rookery on Hood, the remarkable results of hundreds of dives in a copper helmet and bathing suit in the shark-infested waters about Cocos and the Galapagos, a current rip, temporary and on an enormous scale in mid-Pacific. The accomplishment which, scientifically, proved to be the most valuable of all, was the result of my decision to make a ten-day stay in one spot in mid-ocean, Station 74, sixty miles south of Cocos where continual dredging yielded very remarkable collections of fish and crustaceans, equivalent to any two months of the less intensive work. The crustacea alone taken at this place equalled eighty percent of all the rest which we took in the Pacific.

Accurate accounts in popular language have already been brought out by me in "The Arcturus Adventure" published under the auspices of the Zoological Society by G. P. Putnam's Sons, New York City, a companion volume to "Galapagos: World's end."

The origin and evolution of life, men and expeditions are interesting. On the very day of my return from the Galapagos in the *Noma*, I was introduced to a recently elected member of the Board of Managers of the Zoological Society, Henry D. Whiton. Mr. Whiton said to me, "You seem tremendously interested in the Galapagos; if you ever want to go back there I will furnish the steamer if you can get someone else to provide the coal." So from this generous, tentative beginning there crystallized the twenty-four hundred ton steam yacht *Arcturus*, the specified coal, a splendid oceanographic outfit, a captain and a crew, and an expedition of six months' duration, which steamed from New York to the Sargasso Sea, thence to Cocos and the Galapagos, and which secured a host of treasures, from the most microscopic beings which contribute to the surface luminescence of the sea, to a giant devilfish weighing more than a ton.

The two chief contributors to the expedition were Henry D. Whiton, who gave the *Arcturus*, and Harrison Williams who provided three-fourths of the entire cost. Other generous contributors were Marshall Field, Clarence Dillon, Vincent Astor, The American Museum, George F. Baker, Jr., Arthur T. Newbold, Thomas S. Yates and Junius S. Morgan. Other gifts to be recorded are a sounding machine from William H. Trotter; Sets of Oceanographic books from Frederic C. Wolcott; motion picture negatives from George Eastman; Flashlights and batteries from the National



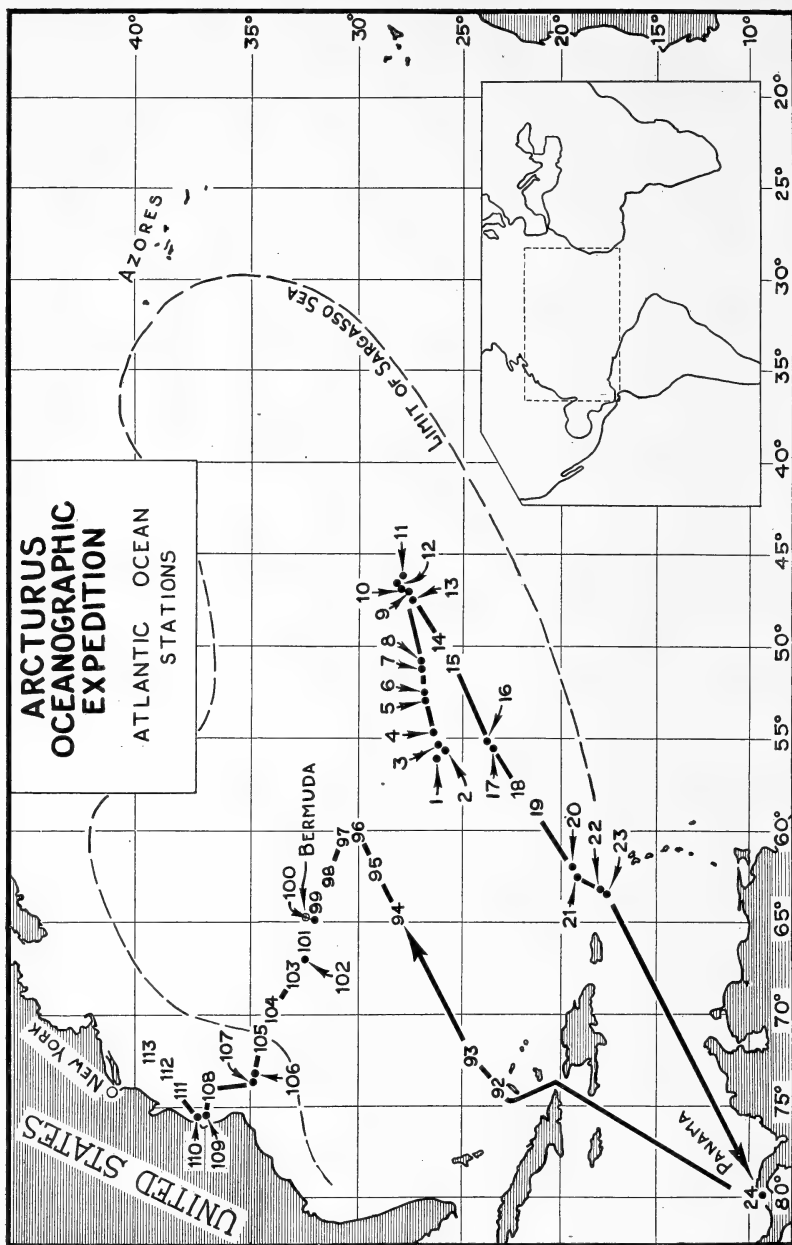


Plate A. Atlantic Ocean Stations. Arcturus Oceanographic Expedition.  
From a drawing by John Tee-Van.

Carbon Co.; a powerful radio set from the Stromberg-Carlson Mfg. Co. and the launch *Pawnee* from Harry Payne Bingham. To Earnest Lester Jones, Chief of the Coast and Geodetic Survey, I am obliged for a host of kindnesses and the loan of valuable instruments, and to the U. S. Fisheries Bureau for the *Albatross* launch and much valuable gear.

The entire responsibility for the sea-going condition of the *Arcturus*, her complete overhauling and the supervision of the building of laboratories, dark-rooms, refrigerators, and oceanographic apparatus was assumed by Mr. J. R. Gordon and the naval architect, Edwin C. Bennett. Capt. Yates acted throughout for Mr. Williams, and it is to the whole-hearted enthusiasm and interest of these gentlemen that the smoothness of operation and general success of the mechanical basis of the expedition was due.

For Captain Howes and First Mate McLaughlin I have nothing but single-minded praise. No more willing, patient and capable seamen ever existed.

The scientific staff was of my own choosing, each of the seventeen members having a definite field of work, which they filled to the full extent of their ability. Without their loyalty, constant enthusiasm and coöperation, nothing of success could have been achieved.

The scientific working personnel was as follows: William Beebe, Director; W. K. Gregory, Associate in Vertebrates; L. Segal, Associate in Special Problems; C. J. Fish, Associate in Diatoms and Crustacea; John Tee-Van, General Assistant; William H. Merriam, Assistant in Field Work; Isabel Cooper and Helen Tee-van, Scientific artists; Ruth Rose, Historian and Technician; Marie Fish, Assistant in Larval Fish; Elizabeth Trotter, Assistant in Fish Problems; Dwight Franklin, Assistant in Fish Preparation; Jay F. W. Pierson, Assistant in Macroplankton; Don Dickerman, Assistant artist; E. B. Schoedsack, Assistant in Photography; Serge Chetyrkin, Preparator; D. W. Cady, Surgeon.

## II. LIST OF STATIONS WITH ACCOMPANYING DATA

The abbreviations used in the individual hauls are as follows:

Station Number	Individual Haul	Position		General Locality	Nearest Sound-ing in Fathoms	Date 1925	Time	Dura-tion of Haul H	D—Dredge	
									RSD—Rope scallop dredge	Depth in Fathoms
		Lat. North	Long. West							
1	T1	26° 10'	56° 07'	580 m. SE of Bermuda		Feb. 23	8.45 A.M.	15		0
	PT1						9.16 A.M.	1		0
	PT2						12.30 P.M.	1		0
	T2						1.40 P.M.	1		0
	PT3						1.40 P.M.	1		0
2	T3	25° 56'	55° 42'	{ 630 m. SE of Bermuda 625 m. NE of Sombbrero		Feb. 23	2.40 P.M.	1		0
	T4						2.40 P.M.	1		0
	V1						3.28 P.M.	2		273-0
	T5						8.00 P.M.	2		0
	T2						8.00 P.M.	2		0
3	T1	26° 19'	54° 53'	650 m. SE of Bermuda	4000	Feb. 24	4.00 A.M.	1		0
	T2						4.00 A.M.	1		0
	T3						6.00 P.M.	45		0
4	V1	26° 19'	54° 53'	650 m. SE of Bermuda	4000	Feb. 24	5.00 P.M.	30		510-0
	T2						6.30 P.M.	1		0
5	V1	26° 42'	52° 59'	745 m. SE of Bermuda	3000	Feb. 25	6.30 P.M.	1		0
	T1						1.56 P.M.	44		357-0
	T2						3.03 P.M.	1		200
	PT1						3.03 P.M.	1		41.8
	T3						3.24 P.M.	1		76.6
6	T1	26° 43'	52° 46'	720 m. SE of Bermuda	3000	Feb. 25	3.30 P.M.	1		0
	PT1						7.50 P.M.	40		0
7	PT1	26° 54'	51° 15'	815 m. SE of Bermuda	3000	Feb. 26	7.40 P.M.	1		30
	PT1						10.51 A.M.	1		640
8	T1	26° 58'	50° 52'	830 m. SE of Bermuda		Feb. 26	8.30 P.M.	1		0
	T2						8.30 P.M.	1		0

Station Number	Individual Haul	Position		General Locality	Nearest Sounding In Fathoms	Date 1925	Time	Duration of Haul H M	Depth In Fathoms	Depth In Meters
		Lat. North	Long. West							
9	T1	27° 42'	46° 59'	1040 m. ESE of Bermuda	2529	Feb. 28	8.35 A.M.	30	0	0
	V1						2.47 P.M.	24	66-0	122-0
	T2						4.28 P.M.	1 53	273	500
	T3								546	1000
	T4								1093	2000
	T5								1367	2500
10	T6								1640	3000
	T1	27° 58'	46° 54'	1040 m. ESE of Bermuda		Mar. 1	8.50 A.M.	2 10	0	0
	T2						8.50 A.M.	2 10	0	0
	T3						8.00 P.M.	1	0	0
11	T4						8.00 P.M.		0	0
	D1	27° 53'	46° 24'	1070 m. ESE of Bermuda		Mar. 2	12.11 P.M.	1 4	2491	4557
	T1			1070 m. SW of Azores			7.30 P.M.	1 30	0	0
	T2						7.30 P.M.	1 30	0	0
12	T3			1115 m. NE of Sombbrero			7.30 P.M.	1 30	0	0
	V1	27° 58'	46° 52'	1020 m. ESE of Bermuda	2180	Mar. 3	8.59 A.M.		109-0	200-0
	V2						9.22 A.M.		273-0	500-0
	VC1							15	37	546-273
	VC2							37	546-273	1000-500
13	VC3							14	1093-546	2000-1000
								57	1640-1093	3000-2000
14	T1	27° 44'	47° 10'	1030 m. ESE of Bermuda		Mar. 3	7.30 P.M.	1 20	0	0
	T2						7.30 P.M.	1 20	0	0
15	T1	26° 10'	50° 00'	890 m. NE of Sombbrero		Mar. 4	7.45 P.M.	1	0	0
	T2						7.45 P.M.	1	0	0
	T3						7.45 P.M.	1	0	0
16	PT1	{ 12 noon 25° 29'			2790	Mar. 5	10.20 A.M.	3 3	500	909
	PT2						10.20 A.M.	3 15	250	450
	PT3			830 m. NE of Sombbrero			6.43 P.M.	1 12	250	450
	T1		51° 00'				6.43 P.M.	1 15	0	0
	T2						6.43 P.M.	1 15	0	0
17	T3						6.43 P.M.	1 15	0	0
	PT1	23° 42'	55° 09'	570 m. NE of Sombbrero		Mar. 7	9.30 A.M.	4	250	450
18	T1	23° 25'	55° 31'	540 m. NE of Sombbrero		Mar. 7	8.00 P.M.	1	0	0
	T2						8.00 P.M.	1	0	0
19	T1	22° 13'	57° 44'	380 m. NE of Sombbrero		Mar. 8	8.00 P.M.	1	0	0
	T2						8.00 P.M.	1	0	0

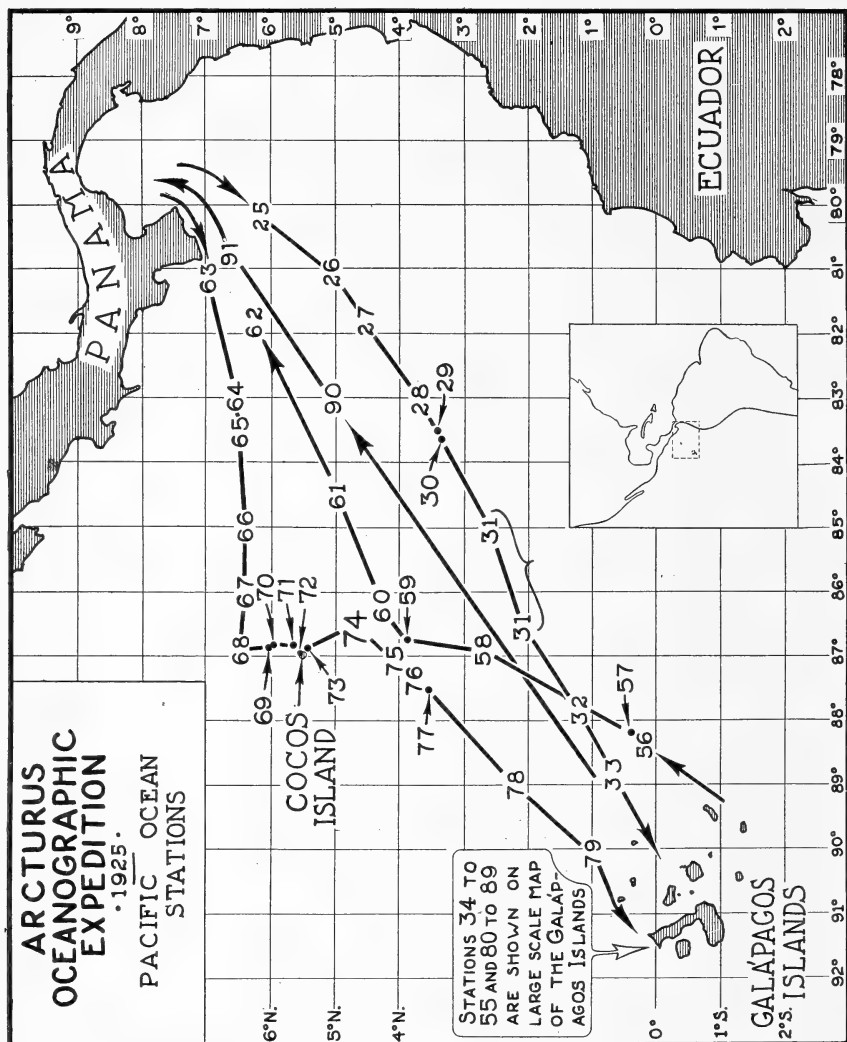


Plate B. Pacific Ocean Stations. Arcturus Oceanographic Expedition.  
From a drawing by John Tee-Van.

Station Number	Individual Haul	Position		General Locality	Nearest Sound-ing in Fathoms	Date 1925	Time	Dura-tion of Haul H M	Depth in Fathoms	Depth in Metres
		Lat. North	Long. West							
19	OT1 PT1 T1	21° 10'	58° 46'	320 m. NE of Sombrero	3146	Mar. 9	10.00 A.M. 2.30 P.M. 7.00 P.M.	4 2 2	250 250 0	450 450
20	V1	19° 21'	61° 57'	100 m. NE of Sombrero		Mar. 12	2.52 P.M.	8	109-0	200-0
21	T1 T2 T3	10° 07'	62° 31'	65 m. NE of Sombrero		Mar. 12	8.00 P.M. 8.00 P.M. 8.00 P.M.	1 1 1	0 0 0	0 0 0
22	Dip Nets	17° 56'	63° 12'	8 m. S of St. Martin	200	Mar. 13	7.00 P.M.			
23	OT1 OT2 RSD1 RSD2	17° 39'	63° 17'	2 m. SW of Saba		Mar. 14	8.30 A.M. 10.00 A.M. 1.30 P.M. 3.00 P.M.	15 30 1 10	45 250 120 120	82 450 218 218
23a	RSD1 RSD2 BT1 BT2 BT3	17° 39'	63° 16'	2 m. SW of Saba		Mar. 15	1.27 P.M. 2.05 P.M. 3.04 P.M. 3.40 P.M. 4.12 P.M.	10 10 10 9 10	7 54.6 54.6 70 71	12.7 100 100 127 130
23b	RSD1 RSD2 (tangle)	17° 39'	63° 16'	2 m. SW of Saba	478	Mar. 15	9.15 A.M. 10.58 A.M.	10 29	656 820	1200 1500
24	dip nets	9° 22.5'	79° 56'	Colon, Panama		Mar. 21-27				
25	T1 T2 T3	6° 10'	80° 11'	65 m. S of Cape Malo		Mar. 29	7.00 P.M. 7.00 P.M. 7.00 P.M.	1 1 1	0 0 0	0 0 0
26	PT1	5° 03'	81° 18'	120 m. S of Mariato Point	2070	Mar. 30	9.13 A.M. 7.30 A.M. 9.50 A.M. 9.50 A.M. 9.13 A.M. 9.20 A.M.	1 1 20 20 1 40	273 0 0 0 136 19	500 0 0 0 250 35
27	T1	4° 30'	81° 49'	165 m. SW of Mariato Point		Mar. 30	7.00 P.M.	20	0	0
28	T1 T2			260 m. SE of Cocos	1805	Mar. 31	5.15 A.M. 5.15 A.M.	15 15	0 0	0 0

Station Number	Individual Haul	Position		General Locality	Nearest Sounding in Fathoms	Date 1925	Time	Duration of Haul H M	Depth in Fathoms	Depth in Meters
		Lat. North	Long. West							
29	T3 OT1	3° 23'	83° 33'	240 m. SE of Cocos		Mar. 31	8.55 A.M. 9.15 A.M.	1 15	0 273	0 500
	T1 PT1 PT1	3° 23'	83° 34'				3.50 P.M. 3.50 P.M.	30 30	136 273	250 500
	T1 T2						8.00 P.M. 8.00 P.M.	20 20	0 0	0 0
30	PT1 PT2	2° 36'	85° 01'	215 m. SSE of Cocos	1826	Apr. 1	8.45 A.M. 9.15 A.M.	15 20	0 13.6	0 25
	PT3 PT4 T1 OT1	2° 8' 2° 4'	86° 17' 86° 31'				9.00 A.M. 11.00 A.M. 11.00 A.M. 4.00 P.M.	1 2 2 2	0 273 136 0	0 500 250 0
	T1 T2	1° 14'	87° 50'				140 m. N.E. of Tower	1462	Apr. 3	5.40 A.M. 5.40 A.M.
32	T1 PT1 T2 T3	0° 40'	88° 51'	70 m. NE of Tower	1392	Apr. 3	2.00 P.M. 2.27 P.M. 8.00 P.M.	1 1 25 25	0 700 0 0	0 1274 0 0
33	T1 T2	0° 00'	90° 00'	20 m. South of Tower	559	Apr. 4	5.30 A.M. 5.30 A.M.	30 30	0 0	0 0
34	T1 T2	0° 27'	90° 19'	22 m. NE of Indefatigable	710	Apr. 4	9.30 A.M. 4.00 P.M.	30 30	0 0	0 0
	T1 T2	0° 19'	89° 57'	1 m. W of Seymour		Apr. 4-6	7.30 P.M. 7.30 P.M. 11.00 A.M.	30 30 30	0 0 0	0 0 0
35	T1 T2 T3 T4 T5 T6 T7 T8 T9	0° 19'	89° 57'	Darwin Bay, Tower		Apr. 7 8 9 9 10 16 17 18 19	7.30 P.M. 7.30 P.M. 7.10 P.M. 7.30 P.M. 7.30 P.M. 7.30 P.M. 7.30 P.M. 7.30 P.M. 7.30 P.M.	30 30 30 30 30 30 30 30 30	0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0

Station Number	Individual Haul	Position		General Locality	Nearest Sounding In Fathoms	Date 1925	Time	Duration of Haul H	Depth in Fathoms	Depth in Metres
		Lat. North	Long. West							
38	PT1 PT2 T1 T2	0° 17'	90° 02'	7 m. W of Tower	448	Apr. 11	12.13 P.M. 3.23 P.M. 6.45 P.M. 6.45 P.M.	1 35 35	360 500 0 0	545 909 0 0
39	T1 T2 T3 PT1 T4 T5 T6 PT2	0° 05'	91° 11.5'	1 m. off NE coast of Al- bemarle	1039	Apr. 12  Apr. 13	7.30 P.M. 7.30 P.M. 8.10 P.M. 10.48 A.M. 10.48 A.M. 7.15 A.M. 7.15 A.M. 2.57 A.M.	30 30 30 1 1 30 30 57	0 0 0 500 250 0 0 600	0 0 0 909 450 0 0 1090
40	T1 D1	0° 14'	91° 18'	5 m. N of Albemarle	1647	Apr. 14	4.20 A.M. 11.11 A.M.	30 1 36		
41	T1 T2 T3	0° 31'	91° 00'	13 m. W of Abingdon	1409	Apr. 14	6.45 P.M. 9.45 P.M. 7.55 P.M.	30 30 10	0 0 0	0 0 0
42	T1 T2	0° 32'	91° 06'	20 m. W of Abingdon		Apr. 15	4.50 A.M. 4.50 A.M.	25 25	0 0	0 0
43	D1 PT1	0° 34'	90° 47'	½ m. W of Abingdon	431	Apr. 15	10.48 A.M.	32	225	
44	PT1	0° 27'	90° 42'	Midway between Ab- ingdon & Bindloe	548	Apr. 15	3.10 P.M.	50	250	450
45	OT1 T1 T2 T3	0° 20'	90° 10'	12 m. W of Tower	493	Apr. 15	9.35 P.M. 9.30 P.M. 9.30 P.M. 9.35 P.M.	33 30 30 30	205 0 0 200	372 0 0 363
46				Darwin Bay, Tower						
47	T1	0° 03'	89° 50'	23 m. S of Tower		Apr. 20	9.30 P.M.	20	0	0
48	PT1 T1 T2 T3	1° 20' (S)	89° 33'	12 m. E of Hood	174	Apr. 21	4.18 P.M. 4.10 P.M. 4.18 P.M. 4.30 P.M.	27 25 27 15	50 0 50 0	90 0 90 0
49	PT1			10 m. SE of Hood	401	Apr. 21	7.40 P.M.	55	200	363





Station Number	Individual Haul	Position		General Locality	Nearest Sound-ing in Fathoms	Date 1925	Time	Dura-tion of Haul H M	Depth in Fathoms	Depth in Meters
		Lat. North	Long. West							
50	T1	2° 00' (S)	89° 30'	34 m. SE of Hood	1820	Apr. 22	7.40 P.M.	55	200	363
	T2						8.10 P.M.	20	0	0
	T1						12.40 P.M.	35	0	0
	T2						12.40 P.M.	35	400	727
	T3						12.40 P.M.	35	800	1454
	OT1						12.40 P.M.	35	800	1454
51	T4	2° 33' (S)	89° 44'	67 m. S of Hood	1835	Apr. 23	12.40 P.M.	1	35	1200
	T1						12.40 P.M.	1	35	1200
	T2						12.40 P.M.	1	35	1200
	T3						12.40 P.M.	1	35	1200
	PT1						7.00 P.M.	30	0	0
	T5						7.00 P.M.	30	0	0
52	PT1	2° 00' (S)	89° 48'	34 m. S of Hood	1733	Apr. 23	9.00 A.M.	2	273	500
	T1						9.00 A.M.	2	54	100
	T2						9.00 A.M.	2	164	300
	T3						9.00 A.M.	2	273	500
	PT2						2.00 P.M.	1	30	545
	T4						2.30 P.M.	40	800	1454
53	T1	1° 51' (S)	89° 50'	25 m. S of Hood	1733	Apr. 24 Apr. 25	6.30 P.M.	30	0	0
	T2						7.30 P.M.	30	0	0
	T3						7.30 P.M.	30	0	0
	T4						9.00 P.M.	30	0	0
	D1						9.40 A.M.	35	1733	3156
	T1						9.40 A.M.	35	1093	2000
54	T2	1° 22' (S)	89° 39'	Gardner Bay, Hood	1388	Apr. 25 Apr. 26 Apr. 27	9.40 A.M.	35	800	1463
	T3						9.40 A.M.	35	800	1463
	T2						7.20 P.M.	25	0	0
	D2						7.00 A.M.	1	1733	3156
	T1						7.20 P.M.	25	0	0
	T2						7.30 P.M.	20	0	0
55	T3	1° 16' (S)	89° 28'	13 m NE of Hood	1388	Apr. 28	7.30 P.M.	20	0	0
	T1						8.00 P.M.	20	0	0
56	T1	0° 10'	88° 22'	98 m. E of Tower	1388	Apr. 29	3.04 P.M.	44	400	727
	T1						3.04 P.M.	44	800	1463
57	T1	0° 22'	88° 11'	105 m. E of Tower	1388	Apr. 29	8.00 P.M.	30	0	0
	T2						8.00 P.M.	30	0	0
58	T1	2° 42'	86° 56'	170 m. S of Cocos	1388	Apr. 30	8.00 P.M.	30	0	0
	T2						8.00 P.M.	30	0	0

Station Number	Individual Haul	Position		General Locality	Nearest Sound-ing in Fathoms	Date 1925	Time	Dura-tion of Haul H M	Depth in Fathoms	Depth in Metres
		Lat. North	Long. West							
59	T1	3° 52'	86° 43'	105 m. S of Cocos	796	May 1	5.15 A.M.	30	0	0
	T2						9.20 A.M.	1	100	181
	T3						9.20 A.M.	1	300	545
	T4						9.20 A.M.	1	500	909
	T5						9.20 A.M.	1	600	1090
	PT1						9.20 A.M.	1	600	1090
	T6						9.40 A.M.	1	0	0
	T7						2.15 P.M.	1	150	272
	T8						2.15 P.M.	1	300	545
	T9						2.15 P.M.	1	500	909
	T10						2.15 P.M.	1	600	1090
	PT2						2.15 P.M.	1	600	1090
60				90 m. SSE of Cocos						
61	T1	4° 56'	84° 35'	150 m. ESE of Cocos	1690.7	May 2	2.10 P.M.	50	0	0
	T2						1.50 P.M.	1	150	272
	T3						1.50 P.M.	1	300	545
	T4						1.50 P.M.	1	500	909
	T5						1.50 P.M.	1	600	1090
	PT1						1.50 P.M.	1	600	1090
62	T1	6° 16'	80° 48'	60 m. SW of Mariato Point		May 3	8.00 P.M.	30	0	0
63	T1	6° 58'	81° 08'	20 m. W of Mariato Point		May 11	8.00 P.M.	30	0	0
	T2						8.00 P.M.	30	0	0
	OT1						8.00 P.M.	30	0	0
64		6° 34'	83° 00'	250 m. E of Cocos	1036	May 12				
65	T1	6° 30'	83° 33'	215 m. E of Cocos		May 12	6.00 P.M.	15	0	0
	T2						6.15 P.M.	15	0	0
	OT1						8.30 P.M.	30	0	0
	T3						8.00 P.M.	30	0	0
	T4						9.00 P.M.	30	0	0
66	T1	6° 24'	85° 00'	130 m. NE of Cocos	1125	May 13	10.10 P.M.	3	300	545
	T2						10.10 P.M.	3	500	909
	T3						10.10 P.M.	3	600	1090
	PT1						10.10 P.M.	3	600	1090
	T1	6° 24'	86° 00'	78 m. NE of Cocos		May 13	8.05 P.M.	30	0	0
67										
68	T1	6° 27'	86° 54'	50 m. N of Cocos	1676	May 14	5.00 A.M.	30	300	545

Station Number	Individual Haul	Position		General Locality	Nearest Sound-ing in Fathoms	Date 1925	Time	Dura-tion of Haul H M	Depth in Fathoms	Depth in Meters
		Lat. North	Long. West							
69	T2 T3 T4 T5 PT1	5° 56'	86° 52'	20 m. N of Cocos	1334	May 14	9.12 A.M. 9.12 A.M. 9.12 A.M. 9.12 A.M.	1 33 1 33 1 33 1 33	400 500 600 600	727 909 1090 1090
70	T1 T2	5° 58'	86° 50'		1251	May 14	6.45 P.M. 7.55 P.M.	30 35	0 0	0 0
71		5° 38'	86° 48'	10 m. NE of Cocos	335	May 15				
72		5° 32'	86° 59'	Chatham Bay, Cocos		May 14-24				
73	T1 T2	5° 28'	86° 54'	6 m. S of Cocos		May 24	8.00 P.M.	30	0	0
74	T1 T2 T3 T4 T5 PT1 T6 T7 T8 T9 PT2 T10	4° 50'	87° 00'	60 m. S of Cocos	514-900	May 25	9.30 A.M. 9.15 A.M. 9.15 A.M. 9.15 A.M. 9.15 A.M. 9.15 A.M. 2.00 P.M. 2.00 P.M. 2.00 P.M. 2.00 P.M. 2.00 P.M. 7.30 P.M.	1 30 1 33 1 30 1 30 1 33 1 33 1 47 1 47 1 47 1 47 1 47 30	0 150 300 500 600 600 350 450 500 600 600 0	0 272 545 909 1090 1090 636 818 909 1090 1090 0
	V1 V2 V3 VC2 VC3 V4 VC4 VC5 V5 VC6 V6 VC7 V7 T11					May 26			546-0 273-0 164-0 382-273 273-164 273-0 273-0 273-0 273-164 164-0 546-382 382-0 710-546 546-0	1000-0 500-0 300-0 700-500 500-300 500-0 500-0 500-300 300-0 1000-700 700-0 1300-1000 1000-0
							7.15 P.M.	45	0	0



Sta- tion Num- ber	Individual Haul	Position		General Locality	Nearest Sound- ing in Fathoms	Date 1925	Time	Dura- tion of Haul H M	Depth in Fathoms	Depth in Meters
		Lat. North	Long. West							
	T42						2.00 A.M.	30	0	0
	T43						3.00 A.M.	30	0	0
	T44						4.00 A.M.	30	0	0
	T45						5.00 A.M.	30	0	0
	T46						6.00 A.M.	30	0	0
	T47						7.00 A.M.	30	0	0
	T48						8.00 A.M.	30	0	0
	D2						7.00 A.M.	30	787	1430
	T49						9.00 A.M.	30	0	0
	T50						10.00 A.M.	30	0	0
	T51						11.00 A.M.	30	0	0
	T52						12.00 P.M.	30	0	0
	T53						1.00 P.M.	30	0	0
	T54						2.00 P.M.	30	0	0
	T55						3.00 P.M.	30	0	0
	T56						4.00 P.M.	30	0	0
	T57						5.00 P.M.	30	0	0
	T58						6.00 P.M.	15	0	0
	T59						6.15 P.M.	15	0	0
	T60						6.30 P.M.	15	0	0
	T61						6.45 P.M.	15	0	0
	T62						7.00 P.M.	15	0	0
	T63						7.15 P.M.	15	0	0
	T64						7.30 P.M.	15	0	0
	T65						7.45 P.M.	15	0	0
	T66						8.00 P.M.	15	0	0
	T67						8.00 P.M.	1	0	0
						June 2		1	749	1361
	OT7						2.30 P.M.	30	300	545
	T68						2.30 P.M.	1	400	727
	T69							30	500	909
	T70							600	600	1090
	T71							0	0	0
	PT5						7.00 P.M.	1	0	0
	T72						8.00 P.M.	1	0	0
	T73									
						June 3		1	400	727
	T74						9.32 A.M.	8	400	727
	T75						9.32 A.M.	1	400	727
	T76						9.32 A.M.	1	500	909
	T77						9.32 A.M.	1	600	1090
	T78						9.32 A.M.	1	700	1274
	PT6						9.32 A.M.	1	700	1274
	D3					June 4	1.45 P.M.	1	765	1390
75		4° 03'	87° 05'	90 m. S of Cocos						

Station Number	Position		General Locality	Nearest Sound-ing in Fathoms	Date 1925	Time	Dura-tion of Haul H M	Depth in Fathoms	Depth in Metres
	Lat. North	Long. West							
76	3° 45'	87° 22'	110 m. S of Cocos		June 4				
77	3° 34'	87° 33'	125 m. S of Cocos	1205	June 4	8.00 P.M.	1	0	0
78	2° 12'	89° 01'	125 m. NE of Tower	1322	June 5	8.00 P.M.	1	0	0
79	1° 00'	90° 04'	40 m. N of Tower	1249	June 6				
80	00° 44'	90° 45'	7 m. N of Abingdon		June 6	8.00 P.M.	30	0	0
81	00° 10' (S)	91° 31'	Banks Bay, Albemarle	118	June 7				
82	00° 12' (S)	91° 28'	Banks Bay, Albemarle	953	June 7				
83	00° 16'	91° 23'	Tagus Cove, Albemarle		June 7-9				
84	0° 17' (S)	91° 34'	1 m. N of Narborough	627	June 9				
						1.45 P.M.	2	300	545
						1.45 P.M.	2	400	727
						1.45 P.M.	2	450	818
						1.45 P.M.	2	500	909
						7.30 P.M.	2	500	909
						8.00 P.M.	30	0	0
						8.00 P.M.	1	0	0
						9.11 P.M.	1	300	545
						9.11 P.M.	1	400	727
						9.11 P.M.	1	450	818
						9.11 P.M.	1	500	909
						1.55 P.M.	1	300	545
						1.55 P.M.	1	400	727
						1.55 P.M.	1	450	818
						1.55 P.M.	1	500	909
						1.55 P.M.	1	500	909
						7.00 P.M.	1	0	0
						7.00 P.M.	1	0	0
						8.00 P.M.	1	0	0
						8.00 P.M.	1	0	0
					June 11	2.06 P.M.	1	400	828
						2.06 P.M.	1	500	909
						2.06 P.M.	1	600	1090
						2.06 P.M.	1	700	1274
						2.06 P.M.	1	700	1274

Station Number	Individual Haul	Position		General Locality	Nearest Sound-ing in Fathoms	Date 1925	Time	Duration of Haul H M	Depth in Fathoms	Depth in Metres	
		Lat. North	Long. West								
85	T1	0° 25'	91° 42'	3 m. W of Narborough	1900	June 11	8.00 P.M.	1	0	0	
	T1 T2 T3 T4 T5 PT1 T6 T7 T8 T9 T10 T11 OT1	0° 42'	91° 47'	16 m. SW of Narborough		June 12	9.39 A.M. 9.39 A.M. 9.39 A.M. 9.39 A.M. 9.39 A.M. 2.15 P.M. 2.06 P.M. 2.06 P.M. 2.06 P.M. 2.06 P.M. 2.06 P.M. 2.06 P.M.	51 51 51 51 51 1 15 1 18 1 18 1 18 1 18 1 18 1 18	400 500 600 800 1000 0 400 500 600 1090 1454 1818 1000	727 909 909 1090 1454 1818 1818 0 727 909 1090 1454 1818 1818	
87	T1 T2 T3 T4 T5 T6 PT1	0° 00'	91° 53'	21 m. NW of Narborough		1720	June 13	9.11 A.M. 9.11 A.M. 9.11 A.M. 9.11 A.M. 9.11 A.M. 9.11 A.M.	1 49 1 49 1 49 1 49 1 49 1 49	100 400 450 500 600 700	181 727 818 909 1090 1274 1274
	T1 T2 T3 T4	0° 11'	91° 21'	3 m. N of Albemarle		June 13	8.10 P.M. 9.00 P.M. 9.35 P.M. 9.45 P.M.	40 30 5 5	0 0 0 0	0 0 0 0	
89	T1	0° 02'	91° 01'	13 m. E of Albemarle		June 14	8.00 P.M.	1	0	0	0
90	T1 T2	5° 04'	83° 04'	125 m. SE of Cocos			June 18	8.00 P.M.	30	0	0
91	T1 T2	6° 40'	80° 49'	25 m. S of Mariato Point		June 19	8.00 P.M. 8.00 P.M.	30 30	0 0	0 0	0 0
92	T1 T2	22° 59'	74° 17'	Atlantic Ocean 60 m. S of San Salvador		July 3	8.00 P.M. 8.00 P.M.	30 30	0 0	0 0	0 0
93	T1 T2 T3	24° 31'	72° 24'	120 m. E of San Salva-dor		July 4	8.00 P.M. 8.00 P.M. 8.00 P.M.	30 30 30	0 0 0	0 0 0	0 0 0



Station Number	Individual Haul	Position		General Locality	Nearest Sound-ing in Fathoms	Date 1925	Time	Dura-tion of Haul H M	Depth in Fathoms	Depth in Metres
		Lat. North	Long. West							
94	T1	28° 10'	64° 35'	250 m. S of Bermuda		July 9	8.00 P.M.	30	0	0
	T2						8.00 P.M.	30	0	0
	T3						8.00 P.M.	30	0	0
95	T1	29° 13'	62° 00'	270 m. SE of Bermuda		July 10	8.00 P.M.	30	0	0
	T2						8.00 P.M.	30	6 ft.	0
	T3						8.00 P.M.	30	0	0
96	T1	30° 00'	60° 00'	280 m. SE of Bermuda	2875	July 11	8.00 P.M.	30	0	0
	T2						8.00 P.M.	30	0	0
	T3						8.00 P.M.	30	0	0
	V1	30° 01'	60° 03'			July 12	8.00 P.M.	30	0	0
	V2						8.00 P.M.	30	0	0
	T4						8.00 P.M.	30	0	0
	T5						8.00 P.M.	30	0	0
	T6						8.00 P.M.	30	0	0
97	T7						8.00 P.M.	30	0	0
	T8						8.00 P.M.	30	0	0
	PT1						8.00 P.M.	30	0	0
	V1	30° 49'	61° 21'	190 m. SE of Bermuda		July 13	8.56 A.M.	24	820-0	1500-0
	V2						10.11 A.M.	28	546-0	1000-0
	VC1						11.20 A.M.	23	273-164	500-300
	VC2						478-324	23	893-593	500-300
	VC3						546-437	30	1000-800	1000-800
	VC4						437-273	30	800-500	800-500
	VC5						820-546	30	1500-1000	1500-1000
98	T1						8.00 P.M.	30	0	0
	T2						8.00 P.M.	30	0	0
	T3						8.00 P.M.	30	0	0
	VC1	31° 22'	62° 35'	125 m. SE of Bermuda	2587	July 14	10.44 A.M.	51	820-546	1500-1000
	VC2						11.44 A.M.	11	164-0	300-0
99	V2						12.52 P.M.		1093-820	2000-1500
	V3						3.30 P.M.		273-0	500-0
	V4						4.40 P.M.		437-0	800-0
	V5								546-0	1000-0
									820-0	1500-0
100	T1	31° 57'	64° 00'	45 m. SE of Bermuda		July 15	8.00 P.M.	30	0	0
	T2	32° 00'	65° 00'	10 m. S of Bermuda		July 15	8.00 P.M.	30	0	0
	T3						8.00 P.M.	30	0	0



Station Number	Individual Haul	Position		General Locality	Nearest Sounding in Fathoms	Date 1925	Time	Duration of Haul H M	Depth in Fathoms	Depth in Metres
		Lat. North	Long. West							
108	T1	36° 55'	74° 12'	90 m. E of Chesapeake Bay	1091	July 22	11.12 A.M.	1 49	0	0
	T2						11.12 A.M.	1 49	300	545
	T3						11.12 A.M.	1 49	400	727
	T4						11.12 A.M.	1 49	500	909
	T5						11.12 A.M.	1 49	600	1090
	T6						11.12 A.M.	1 49	700	1274
109	D1	36° 56'	75° 28'	30 m. E of Chesapeake Bay		July 23	8.45 A.M.	20	19	36
	D2						8.45 A.M.	20	32	60
110	T1	30° 16'	74° 58'	45 m. E of Chesapeake Bay		July 23	8.00 P.M.	30	0	0
111	PT1	38° 00'	74° 02'			July 24	9.07 A.M.	20	60	109
	D1						11.46 A.M.	54	0	0
112	D2					July 24			382	694
	T1	38° 31'	73° 12'				8.00 P.M.	30	0	0
113	D1	39° 15'	72° 00'	100 m. SE of Delaware Bay 125m. SE of City Hall, N. Y. City	950-1200	July 25	8.52 A.M.	31	633	1150
	T1						11.35 A.M.	1 27	300	545
	T2						11.35 A.M.	1 27	350	636
	T3						11.35 A.M.	1 27	400	727
	T4						11.35 A.M.	1 27	450	818
	T5						11.35 A.M.	1 27	500	909
	T6						10.00 P.M.	30	0	0
	T7						11.00 P.M.	30	0	0
	T8						12.00 A.M.	30	0	0
	T9						1.00 A.M.	30	0	0
	T10						2.00 A.M.	30	0	0
	T11						3.00 A.M.	30	0	0
	T12						4.00 A.M.	30	0	0
	T13						5.00 A.M.	30	0	0
	T14						6.00 A.M.	30	0	0
	T15			July 26			7.00 A.M.	30	0	0
	T16						8.00 A.M.	30	0	0
	T17						9.00 A.M.	30	0	0
	T18						10.00 A.M.	30	0	0
	T19						11.00 A.M.	30	0	0
	T20						12.00 P.M.	30	0	0
	T21						1.00 P.M.	30	0	0
	T22						2.00 P.M.	30	0	0
	T23						3.00 P.M.	30	0	0

Station Number	Individual Haul	Position		General Locality	Nearest Sound-ing in Fathoms	Date 1925	Time	Dura-tion of Haul H M	Depth in Fathoms	Depth in Meters
		Lat. North	Long. West							
	T24					July 27	4.00 P.M.	30	0	0
	T25						5.00 P.M.	30	0	0
	T26						6.00 P.M.	30	0	0
	T27						7.00 P.M.	30	0	0
	T28						8.00 P.M.	30	0	0
	T29						9.00 P.M.	30	0	0
	VC1							0	0	0
	VC2							437-273	800-500	
	V1							546-437	1000-800	
	V2							546-0	1000-0	
	V3					July 28		229	419-0	419-0
	V4							164-0	300-0	300-0
	V5							54-0	100-0	100-0
	T30						3.20 P.M.	53	54	100
	T31						3.20 P.M.	53	109	200
	T32						3.20 P.M.	53	164	300
	T33						8.30 P.M.	30	0	0
	T34						9.29 A.M.	31	500	909
	T35						9.29 A.M.	31	600	1090
	T36						9.29 A.M.	31	700	1274
	T37					July 29	9.29 A.M.	31	800	1454
	T38						9.29 A.M.	31	900	1636
	T39						9.29 A.M.	31	1000	1818
	PT1						9.29 A.M.	31	1000	1818
	T40						2.04 P.M.	44	700	1274
	T41						2.04 P.M.	44	800	1454
	T42						2.04 P.M.	44	900	1636
	T43						2.04 P.M.	44	1000	1818
	T44						2.04 P.M.	44	1100	2000
	T45						2.04 P.M.	44	1200	2181
	PT2						2.04 P.M.	44	1200	2181
	T46						8.00 P.M.	30	0	0
	D2					July 29		69	69	127
	D3							69	69	127
	PT3							69	69	127



Depths Metres	Sta. 50		Sta. 51		Sta. 56		Sta. 59		Sta. 66		Sta. 68		Sta. 74		Sta. 84	
	C.	C.T.	C.	C.T.	C.	C.T.	C.	C.T.	C.	C.T.	C.	C.T.	C.	C.T.	C.	C.T.
0	0	25.9	-0.05	23.45	0	27.2	0	27.5	0	28.5	0	28	0	27.5	0	22.1
25	0	—	—	22.1	0	23.2	0	27.9	0	26.5	0	28.65	0	27.1	0	20.6
50	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
75	-0.05	22.45	0	21.47	-0.15	18.75	+0.05	22.55	-0.15	18.3	-0.1	23.67	0	19.97	—	22.0
100	—	17.7	-0.05	—	-0.1	—	+0.05	—	-0.15	—	-0.05	—	-0.15	—	—	—
150	-0.15	15.45	-0.05	20.87	-0.1	16.25	-0.2	14.3	-0.2	13.97	-0.25	15.57	-0.25	14.57	-0.05	18.75
250	-0.15	—	0	—	-0.15	—	-0.2	—	-0.2	—	-0.2	—	-0.2	—	-0.05	—
300	-0.2	11.6	-0.2	11.9	-0.2	12.22	-0.25	11.3	-0.2	11.27	-0.25	11.20	-0.2	11.62	-0.2	11.8
450	-0.2	—	-0.2	—	-0.25	—	-0.25	—	-0.25	—	-0.3	—	-0.2	—	-0.2	—
500	-0.25	8.32	-0.3	7.9	-0.25	8.25	-0.25	8.1	-0.25	7.92	-0.3	8.3	-0.25	8.35	-0.25	7.95
1000	-0.4	4.8	-0.3	—	-0.25	—	-0.25	—	-0.2	—	-0.3	—	-0.25	—	-0.25	—
1500	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2000	-0.5	3.17	-0.5	—	-0.5	—	—	—	—	—	—	—	—	—	—	—
2500	-0.45	2.4	-0.5	—	-0.5	—	—	—	—	—	—	—	—	—	—	—
3000	-0.45	1.95	-0.55	—	-0.45	—	—	—	—	—	—	—	—	—	—	—
	-0.45	1.72	-0.45	—	-0.45	—	—	—	—	—	—	—	—	—	—	—
	-0.5	—	-0.5	—	-0.5	—	—	—	—	—	—	—	—	—	—	—

Note: C. = Correction.

C.T. = Corrected Temperature—or average of 2 corrected readings.

\* 2 sets thermometers taken at this depth: 1 = first set, 2 = second set.

## IV. CHLORINE IN SEA WATER 0/00.

## BY TITRATION WITH SILVER NITRATE

MADE BY JOHN B. WILSON, ASSOC. CHEMIST.

*Bureau of Chemistry, U. S. Department of Agriculture*

Station No.	Surface	25M	50M	75M	100M	250M	300M	450M	500M	1000M	1500M	2000M	2500M	3000M
3.							19.36							
5.	20.46		19.48				20.11		19.92	19.57				
9.	20.46		20.52		20.64		20.70		20.26	19.74				
15.	20.46				20.60		20.26		19.97	19.46	19.28			
16.	20.35				20.16		20.05		19.51	19.26	19.40			
20.	20.00				19.37		19.22		19.22					
26.	18.92		19.45		19.38		19.31		19.21	19.17				
28.	18.70		19.21		18.89				19.23					
31.	18.75	18.74	18.80		18.44	19.29	19.27	19.33	19.34					
31B.	18.33		19.47			19.30	19.31	19.15						
33.					19.40									
35.	18.87	18.89	19.26			19.25								
38.	18.62	18.76	18.95											
39.	18.66	18.69	19.16		19.36		19.24							
40.	18.46	17.79	19.17	19.45			19.29							
50.	18.78	19.12	19.28	19.44			19.30		19.34	19.06	19.11	19.11	19.14	19.19
51.	18.91	19.45	19.54		19.34		19.34		19.20					
56.	18.77	18.96	19.44		19.48		19.36		19.20					
59.	17.76	18.17	18.86		19.30		19.17		19.10					
66.	17.79	18.73	19.16		19.27		19.32		19.18					
68.	18.24	18.61	19.06		19.25		19.25		19.16					
74.	17.88	18.25	19.98		19.38		19.25		19.10					
84.	19.32	19.32	19.56		19.45		19.22		19.18					
96.	20.14				20.21		20.23		20.08	20.03	19.39			
98.	20.20				20.20		20.13		20.14	19.59	19.36			
99.	20.19				19.25		20.14			20.15				
101.	20.10				19.85		20.11		20.06	19.58	19.39			
103.	19.97				20.16		20.20		20.18	19.55	19.41			
104.	20.00				20.15		20.14		19.76	19.46				
105.														

Land-locked Lagoon, Tower Island April 17, '25 Surface. Edge 22.14

Land-locked Lagoon, Tower Island April 17, '25 Surface. Center 25.40

Green Water, near Volcano, Albemarle Island 18.72

## V. RÉSUMÉ OF STATION AND HAUL RESULTS

As introduction to this preliminary survey of the plankton hauls of the *Arcturus* Expedition it may be worth while to quote a few paragraphs from one of my recently published popular accounts.\*

One dark, moonless evening I put out a silk surface net the mouth of which was round, and about a metre, or a yard, in diameter.

At the further end of the net a quart preserve jar was tied to receive and hold any small creatures which might be caught as the net was drawn slowly along the surface of the water. This was done at the speed of two knots, and, as I have said, was continued for the duration of one hour. When drawn in, the net sagged heavily and we poured out an overflowing mass of rich pink jelly into a white, shallow tray. This I weighed carefully, and then took, as exactly as possible, a one-hundred-and-fiftieth portion. I began to go over this, but soon became discouraged, and again divided it and set to work on one-sixth of the fraction on which I had first started. After many hours of eye-straining and counting under the microscope, I conservatively estimated my one-hundred-and-fiftieth part of the hour's plankton haul as follows:—

Feathery copepods—Candace-like.....	7,920
Bright blue copopods—Pontella-like.....	71,400
Other copopods—Calanus-like.....	139,320
Bivalve crustacea—Ostracods.....	4,920
Short-eyed shrimps.....	720
Siphonophores.....	14,400
Heliced snails.....	8,880
Purple Ianthina snails.....	13,440
Egg masses of snails.....	1,080
Free eggs, various.....	5,280
Clio-like pteropods.....	2,520
Limacina-like pteropods.....	240
Cavolinia-like pteropods.....	960

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Total of specimens.....271,080

If we multiply this by one hundred and fifty we get forty million, six hundred and sixty-two thousand individuals. Please remember that this is a very conservative estimate of only a few of the more easily counted groups in one small haul of an hour's duration, and the magnitude of the life of the sea will begin to dawn

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\* The *Arcturus* Adventure, pp. 199-200.



upon our minds. Twelve hours later—in full daylight—I repeated the haul as closely as possible and, instead of forty million, I captured about one thousand individuals of the corresponding groups.

The above figures give a more vivid meaning to the terms of relative occurrence, such as Abundant, Common and Many, which I have used in the following data. At my suggestion Dr. C. J. Fish kept a relatively accurate tally of the more easily recognizable groups of invertebrates of the plankton hauls, while I made a corresponding catalogue of the fish. For this purpose there was no attempt at specific identification, but the mere listing, in relative abundance, of the hundred-odd groups which leaped to the eye out of the quarts of millions of living organisms.

Reference to the Station data given in preceding pages will furnish the details of each haul, which can then be correlated with the present scheme. Future papers will present the exact identification of the various components.

As regards the symbols of relative abundance and rarity, after considerable thought, I have altered the scheme which I use in ecological work in the jungle,\* and have made a compromise with that of Dr. Fish. This is as follows:—

A—Exceedingly Abundant

C—Common; Abundant

M—Many

F—Few

R—Rare; Very Few

Applying this to the count made on page 27 I should adopt the following:

A—Calanus copepods	139,320
C—Pontella copepods	71,400
M—Siphonophores	14,400
F—Limacina pteropods	240

The sequence of groups under each haul is by relationship. In the case of unidentified species I have sometimes used arbitrary popular names which at least indicate the general group.

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\* *Zoologica*, VI, No. 1, p. 43.

## VI. PACIFIC DEPTH PLANKTON HAULS

As closing nets were not used, there is, in the following tables, a small percentage of error, from the organisms, however few in number, which entered the nets during their comparatively rapid ascent to the surface. Rather than attempt to orient these I have chosen to include the sporadic occurrence of such obviously out-of-place organisms as *Halobates* at 300 and 600 fathoms and *Glaucus*, *Lanthina* and *Pontella* at 600 and 800 fathoms.

## 20—Fathom Plankton

Station and Haul	26 OT1
Siphonophores (transparent)	M
Jellyfish (transparent)	F
Sagitta (large)	A
Firola	M
Copepods	R
Eucalanus	R
Amphipods	M
Hyperid Amphipods	M
Lucifer	M
Macruran larvae	M
Bachyura megalops	1
Squilla larvae	C

## 50—Fathom Plankton

	48 T2
Hydromedusae	M
Sagitta (small)	C
Tomopteris	1
Crescis acicula	C
Cresia conica	C
Cavilina uncinata	2
Copepods (small pink)	C
Eucalanus	F
Hyperids (yellow)	F
Euphausiids (young)	F
Porcellana larvae	1
Halobates	1

## 100—Fathom Plankton

	59 T2	86 PT1	87 T1
Heliozoans (red)	M		
Radiolarians			M
Liriope			1
Tomopteris	1		
Gastropods	F		
Atlanta	2	1	
Cymbulia sibogae	1		
Copepods (small pink)	F		
Caligus (brown)			F
Hyperids (yellow)			1
Gnathophausia willemoesia		F	
Euphausiids	F		
Macrurans (red)		R	

## 150—Fathom Plankton

	26 T4	29 T1	31 T1	51 T2	59 T7	61 T2	74 T2
Siphonophores	M		M				C
Pleurobrachia (small)						F	
Beroe (pink)						F	
Annelids	1						R
Tomopteris	R						
Sagitta	C		F		F	R	F
Clio	C						
Firola	F			R		F	F
Hyalocylix striata		F	C		M	M	M
Creseis		R	C				R
Cavolina longirostris			M				
Atlanta				R			
Clionopsis grandis				R			
Diacra quadridentata						R	R
Limacina inflata							A
Cymbulia sibogae					A		

150—Fathom Plankton (*Continued*)

	26 T4	29 T1	31 T1	51 T2	59 T7	61 T2	74 T2
Glaucus			2				
Ostracods (small white)						C	F
Ostracods (orange)	F				F	F	F
Copepods (small pink)				C	F	M	
Eucalanus elongatus	A			M			R
Pontella			C		R		
Sapphirina	F		R				F
Mysids			R		R		
Candace					R		
Hyperids	M		A				
Phronima					M	M	M
Oxycephalids							R
Gammarids (orange)							F
Other Amphipods	R	R	A	F	F		
Euphausiids		C				A	R
Brachyura megalops		1					
Nauplius		1					
Phyllosoma			3				
Squilla larvae	F						
Salpa			C				R

## 200—Fathom Plankton

	49 PT1
Sagitta (large, transparent)	R
Limacina inflata	C
Limacina lesueurii	C
Creseis acicula	M
Creseis conica	M
Copepods (Small pink)	M
Pontella	M
Mysids	R
Euphausiids (small, white)	C
Euphausiids (pale pink)	1
Megalops	A
Phyllosoma	Z
Squilla larvae	C

300—Fathom Plankton

	26 PT1	28 PT1	51 T3	51 PT1	59 T3	59 T8	61 T3	66 T1	68 T2	74 T3	74 T14	74 T18	84 T1	84 T7	84 T11
Medusae (transparent)							R								
Beroe (small)									R					R	
Pleurobrachia									R						
Atolla														R	
Diphyes															R
Siphonophores							C				R		R		
Pelagothuria															R
Annelids (brown)															
Annelids (pink)					R									R	
Sagitta (large white)	C			M	R			R						F	F
Sagitta (pink)			R		R			R							
Firola	M	F	F		R		R	R							R
Clio	M									R					
Diaca quadridentata										R					
Diaca trispinosa			R	R											
Cavolina uncinata			R								R				
Clionopsis grandis			R												
Cymbulia sibogae															
Crescis acicula					R	F									
Hyalocylix								R					R		
Atlantia								R		R					
Glaucus							R <sup>1</sup>	R							
Ostracods (orange)					R			R		C	R				
Copepods (small pink)					A			R				F		F	

300—Fathom Plankton (Continued)

	26 PT1	28 PT1	51 T3	51 PT1	59 T3	59 T8	61 T3	66 T1	68 T2	74 T3	74 T14	74 T18	84 T1	84 T7	84 T11
Copepods (large red)	F			F	F										
Eucalanus					A	A	A	A	M	A		M	F	F	A
Pontella													F		
Lucifer										R					
Gnathophausia (small red)					R									R	
Phronima			R	R	F	R									
Amphipods (orange)				F	F				R						R
Hyperids					R										
Oxycephalids										R			R	R	
Gammarids (orange)													F		
Amphipods (transparent)							F								
Amphipods (pale slate)							M								
Euphausiids (pink patches)			R			C		M	A	C	R	F			F
Euphausiids (small white)						M					C	F	A		
Other Schizopods	C														
Macrurids (red and white)														R	
Megalops (red)															
Shrimps (scarlet)	M				F										
Shrimps (orange)	F														
Salpae	M									R					
Doliolum	A				M										
Pyrosoma					R										
Halobates									R <sup>1</sup>				R <sup>2</sup>		

## 400—Fathom Plankton

	50 T2	56 T1	68 T3	84 T8	84 T19	86 T1	87 T2
Ctenophores (orange)		R		F			
Beroe (pink)				R			
Atolla				R			
Actinarians (orange)				F			
Siphonophores	R						
Porpita	R <sup>2</sup>		R <sup>1</sup>				
Pelagothuria						R	R
Annelids (large white)				R			
Sagitta (large white)	R						F
Eukrohnja (pink)	F	M		R	R	F	F
Firola			R				
Cymbulia		R			R		F
Clio pyramidata	F				F	R	
Clionopsis krohni					R		
Limacina	F						
Hyalocylix	F						
Creseis conica	F						
Creseis acicula	R						
Atlanta	R						
Limacina	R						
Cavolina	R						
Diacra trispinosa	R						
Cymbulopsis	F						
Glaucus	R <sup>3</sup>		R <sup>2</sup>				
Ianthina	R <sup>1</sup>						
Squids			R				
Ostracods	F		F				
Copepods (large red)	F			M	F	F	M
Eucalanus	A		A		M	C	F
Pontella	R						
Gnathophausia willemoesia		R				F	R
Isopods (black)						R	R
Hyperids	F	F					
Phronima	F			R			
Gammarids (pink)						M	
Oxycephalids			R	M		F	R
Other Amphipods (white)	M						

400—Fathom Plankton (*Continued*)

	50 T2	56 T1	68 T3	84 T8	84 T19	86 T1	87 T2
Amphipods (orange)					R	R	
Euphausiids (adults)	M	M	M	F	M	C	M
Macrurids (red)		F			F		F
Lucifer	M						
Eryoneicus						R	
Squilla (larvae)	R						
Salpa			R				

## 450—Fathom Plankton

	74 T7	74 T15	74 T19	84 T3	84 T9	84 T13	87 T3
Actinians (orange)					R		
Periphylla					R		
Hydromedusae (white)	R						
Hydromedusae (yellow)			R				
Siphonophores		R		R			
Ctenophores		R					
Beroe				R			R
Annelids (orange)		R			M		
Eukrohnia (orange)	F		F		R		
Clio balantium	R						
Cymbulia	R						
Diacra quadridentata		R					
Peracelis			R				
Firola				F	R		
Ostracods (red)	F		R	R			
Copepods (red zone)	M	F		C		C	
Eucalanus		A	M			A	
Mysids (red)	R						
Gnathophausia (small red)			R	F	F	F	
Hyperids (small pink)		R					
Gammarids (orange)					R		
Phronima	R	R	R				
Oxycephalids	R	R		R	R		
Amphipods (large red)	F	R	F				R
Euphausiids (red)	R	F	F				
Euphausiids (small white)		A					
Eucopa (deep red)							R
Macrurids (red and white)					F	F	



## 450—Fathom Plankton (Continued)

	74 T7	74 T15	74 T19	84 T3	84 T9	84 T13	87 T3
Megalops (pink)				F			
Lucifer				F			
Shrimps (small red)			R				
Benthophausia (orange)					F		
Squilla (larvae)				R		R	
Isopods (brown)	R		R	F			

## 500—Fathom Plankton

	59 T4	59 T9	61 T4	66 T2	74 T4	74 T8	74 T27	84 PT1	84 T10	84 T14	84 PT3	84 T20	86 T2
Medusae (small white)		M											
Pleurobrachia (pink)		C	F		R								
Beroe (pink)			R			R		R	F	R			
Periphylla			R										
Atolla					F	R							
Actinians (larval scarlet)										M			
Annelids (yellow)										F			
Annelids (orange)	F												
Sagitta (salmon)	M	M	M	M	F	F	F	R				F	R
Sagitta (transparent)	R		F										
Planarians (orange)		R											
Nemertians													R
Firola	R		F	F	R			R		R	R		R
Peracelis													
Creseis conica				R									
Creseis acicula				R									
Atlanta				R									
Clio pyramidata				R								F	
Clio balantium			R										
Hyalocylix				R									
Peracles			F				F						
Clionopsis krohni								R					
Cymbulia												R	
Octopus (fragile red)			R										
Ostracods (orange)	F		F		M					R			
Gigantocypris (small)													R G
Copepods (pink, red)	M	R	F	M	F	M	F	F				C	F
Eucalanus	M			C	C		C			C		M	C

500—Fathom Plankton (*Continued*)

	59 T4	59 T9	61 T4	66 T2	74 T4	74 T8	74 T27	84 PT1	84 T10	84 T14	84 PT3	84 T20	86 T2
Calanids (small)	C												
Mysids (orange, red)			R		M							R	
Gnathophausia					R			C		C	C		R
Isopods (black)		R			F	F		R	F			R	F
Phronima		R		R				R					
Gammarids (orange, pink)		R		F		F	F			R			M
Gammarids (slate color)		R											
Oxycephalids						R	R						M
Euphausiids (white)	C	M					F						C
Euphausiids (pink patches)	F			F	M								
Schizopods (scarlet)								M					
Porcellana (larvae)								R					
Macrura (red and white)								C			C	F	R
Macrura (large, snow white)											F		
Eryoneicus								R					
Magalops (black, red)			R									R	R
Shrimps (small red)	R		F	F	R					R			
Shrimps (large red)	F		F		F								
Squilla (post larval)											R		
Salpa (small blue)													A
Salpa zonaria			R										
Doliolum	F												

## 550—Fathom Plankton

	74 T20
Atolla	F
Eukrohnia (red)	F
Diacra quadridentata	R
Eucalanus	A
Gnathophausia (small)	R
Mysids (red larvae)	R
Isopod (black)	R
Oxycephalids	R
Amphipods (fragile pink)	R
Euphausia (pink and white)	M
Benthophausia	F
Shrimp (small red)	R

## 600—Fathom Plankton

	59 T5	59 PT1	59 T10	59 PT2	61 T5	61 PT1	66 T3	66 PT1	68 T5	68 PT1	74 T5	74 PT1	74 T9	74 PT2	74 T16	74 PT3	74 T21	84 T21	86 T3	87 T5
Ctenophores											R				R		R			
Hydromedusae (pink)											F									
Bolina																				
Periphylla					R				R		R					R				
Pleurobrachia						F														
Atolla																				
Siphonophores											R									M
Diphyes													F							
Actinians (small pink)																			R	
Annelids (orange)					F						R								R	
Annelids (white)																				
Sagitta (transparent)					F										F					
Sagitta (pink)	F	C	M	M	M	C	M	M	F		M	R	F	F	F		F			F
Tomopterus											R									
Nemertians (orange)																	R			R
Firola			R			F	F	R		R	R				R					
Atlanta	R						F	F												
Cymbulia			R	F				R										R		R
Hyalosyllis siria			R																	
Olio pyramidata																		F		
Creseis acicula							F													
Cavolina uncinata							R	R				F				R	R			
Peracles															R	R	R			

600—Fathom Plankton (Continued)

600—Fathom Plankton. (Continued)

	59 T5	59 PT1	59 T10	59 PT2	61 T5	61 PT1	66 T5	66 PT1	68 T5	68 PT1	74 T9	74 PT1	74 T9	74 PT2	74 T16	74 PT3	74 T21	84 T21	86 T3	87 T5
Phyllosomes							R													
Macrurans (red)						R					R						R			F
Benthophausia (red)																			R	
Shrimps (large red)	R	M		M			M	C	F	C	F	F		R	R	R	R			
Squilla (larvae)				R				R		C		F				F				
Doliolum										F										
Appendicularia						F														
Salpa zonaria (purple)																				
Halobates	R <sup>1</sup>						R <sup>1</sup>					R	R	R						

## 700—Fathom Plankton

	33 PT1	83 T22	84 PT4	87 T6	87 PT1
Actinians (larvae)		R			
Siphonophores					
Eucopa (deep wine color)				R	
Atolla wyvilli	R				
Halierecas papillosum	F				
Homoconema typicum	R				
Aequorea globosa	R				
Siphonophore	R			M	
Annelids (yellow)		R			
Sagitta (transparent)	M				
Sagitta (salmon)	C	F		M	
Nemerteans		R			
Firola	R		R	R	R
Atlanta	R	R	R		
Cavolina tridentata				R	
Cavolina uncinata			R		
Clio pyramidata	R	F	C		
Clio cuspidata				R	R
Cymbulia		F	F		
Squid (red)		R		R	
Ostracods (pink)	R				
Gigantocypris agassizi			R		
Copepods (large pink)	M			F	
Eucalanus		M		M	
Gnathophausia			F		
Gnathophausia brevispinis				R	F
Mysis		R			
Amphipods (pink)	F				
Hyperids	R				
Oxycephalids			R		
Gammarids (pink)				F	
Macrurus (red and white)			M		R
Megalops (large)	R				
Porcellana (zoea)	R				
Zoea (long-spined)	R				
Benthophausia		R			
Shrimp (red)					R

700—Fathom Plankton (*Continued*)

	33 PT1	83 T22	84 PT4	87 T6	87 PT1
Squilla (larvae)	R	R	R		
Salpa cylindrica	R				
Euphausiids		M	M	F	M

## 800—Fathom Plankton

	50 T3	50 OT1	53 T2	56 PT1	86 T4
Ctenophores					R
Annelids (pink)	R				
Sagitta (large transparent)	R		M	R	
Sagitta (pink)	F		R	R	F
Creseis conica	M		M		
Creseis acicula	F				
Clio pyramidata	F		R		
Clio balantium			R		
Hyalocylis	R		R		
Firola			R		F
Cymbulia					R
Ianthina	R <sup>1</sup>				
Squid					R
Ostracods (small orange)			R		
Gigantocypris			R		
Copepods (red)	M		M		M
Eucalanus	A				
Pontella	F				
Gnathophausia (red)			R	F	F
Isopod (black)	R			R	
Hyperids (white)	M				
Hyperids (red)				R	
Oxycephalids					R
Gammarids (orange)					M
Euphausiids (red)			M	F	M
Schizopods (pink)	M				
Macrurans (red)			R	R	R
Benthophausia (orange)			R		
Shrimp (red)	R	R		F	
Squilla (larvae pink)		R			
Salpae	F				

## 1000, 1100, and 1200—Fathom Plankton

	1000 fathoms 86 T5	1100 fathoms 53 T1	1200 fathoms 50 T4
Beroe (small pink)			R
Atolla	F		
Pelagothuria	F		
Sagitta (large transparent)		F	M
Sagitta (pink)	F	F	
Firola	R		
Atlanta		R	
Cavolina longirostris		R	
Creseis conica		R	
Creseis acicula		R	
Notabbranchia		R	
Hyalocylix striata		R	
Clio pyramidata			A
Eucalanus	C	A	
Gnathophausia (large red)	F		R
Isopods (black)	R		
Amphipods (pink fragile)			F
Gammarids (pink)	C		
Gammarids (orange)	F		
Oxycephalids	M		
Euphausid (pink)			R
Euphausids (white)	C	F	F
Porcellana (large)			R
Benthophausia (red)	F	F	
Shrimps (large red)		M	F
Squilla (post larva)			R
Ostracods (scarlet)	R		



VII. RELATIVE ABUNDANCE OF FIFTY-SEVEN GROUPS OF INVERTEBRATES IN  
PACIFIC SURFACE HAULS

	Number of Occurrences in 47 Hauls	Abundant	Common	Many	Few	Rare	Relative Abundance based on 10-7-5-3-1 Ratio
Siphonophores	14	2	2	2	3	5	58
Porpita	13		1	2	8	2	43
Hydromedusae	6	1		1	3	1	25
Ctenophores	8	1		1	5	1	31
Liriope	5		2		2	1	21
Stomatoca derissa	3			1	2		11
Mneopsis	1	1					10
Pleurobrachia	1		1				7
Physalia	1					1	1
Sagitta	31	7	8	7	7	2	184
Annelids	3				2	1	7
Creseis conica	17		5	2	8	2	71
Creseis acicula	12		5	3	3	1	60
Atlanta	9	1		3	1	4	32
Glaucus	12			2	6	4	32
Ianthina	11			2	5	4	29
Diacra quadridentata	7	1		1	2	3	24
Firola	7		1	2	1	3	23
Gastropod larvae	2	2					20
Limacina	4	1	1			2	19
Hyalocylix striata	5			1	4		17
Squid	8			2		6	16
Clio	5			1		4	9
Cavolina uncinata	5				1	4	7
Cavolina longirostris	2				1	1	4
Cymbulia	2					2	2
Peracles	1					1	1
Pneumoderma boasi	1					1	1
Euphausiids	30	6	9	4	11		176
Pontella	30	2	6	11			117
Copepods, small	13	7	4	1	1		106

Relative Abundance of Fifty-seven groups (*Continued*)

	Number of Occurrences in 47 Hauls	Abundant	Common	Many	Few	Rare	Relative Abundance based on 10-7-5-3-1 Ratio
Megalops	19	3	1	4	8	3	84
Phyllosomas	18	2	3	3	5	5	76
Hyperids	17	1	3	3	7	3	70
Squilla larvae	15	1	2	2	5	5	54
Lucifer	12	1	1	4	5	1	53
Zoea	10	2	1	1	2	4	42
Amphipods	8	1		2	5		35
Eucalanus	10	1		2	4	3	35
Mysids	6	1	2		3		33
Calanus	3	3					30
Monops	7		2		4	1	27
Schizopods	3	1	1		1		20
Sapphirina	3		1	1	1		15
Macrurus larvae	3		1	1	1		15
Candace	3		1		1	1	11
Acartia	1	1					10
Ostracods	1		1				9
Isopods	4				1	3	6
Gammarids	1				1		3
Hippa larvae	3					3	3
Sergestes larvae	2					2	2
Phronima	1					1	1
Halobates	27			5	21	1	89
Salpae	13	3	5		4	1	78
Doliolum	1				1		3
Pyrosoma	1					1	1

VIII. RELATIVE ABUNDANCE OF SIX MAJOR GROUPS OF INVERTEBRATES IN FORTY-SEVEN SURFACE HAULS IN THE PACIFIC

Crustacea	1033	52.4 per cent
Mollusca	367	18.7 per cent
Coelenterata	207	10.5 per cent
Annelida	191	9.7 per cent
Insecta	89	4.5 per cent
Urochorda	82	4.2 per cent



# ZOOLOGICA

## SCIENTIFIC CONTRIBUTIONS OF THE NEW YORK ZOOLOGICAL SOCIETY

DEPARTMENT OF TROPICAL RESEARCH  
ARCTURUS OCEANOGRAPHIC EXPEDITION

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### THE ARCTURUS: OPERATION AND EQUIPMENT

BY JOHN TEE-VAN

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# THE ARCTURUS: EQUIPMENT AND OPERATION.\*<sup>1</sup>

BY JOHN TEE-VAN

*Assistant, Department of Tropical Research.*

(Figs. 2-28 incl.)

## OUTLINE

INTRODUCTION

THE SHIP—LABORATORIES, STOREROOMS, ETC.

BOOM-WALK

BOW-PLATFORM

SOUNDING MACHINERY

TRAWLING AND DREDGING MACHINERY

METER WHEELS OR MEASURING DEVICES

TRAWLS AND DREDGES

TANGLES

TOW-NETS

VERTICAL NETS

METHODS OF ATTACHING NETS

MISCELLANEOUS FISHING GEAR

THERMOMETERS AND WATER SAMPLE BOTTLES

LABORATORY EQUIPMENT

AQUARIUMS

PHOTOGRAPHIC EQUIPMENT

WORK-SHOP EQUIPMENT

SMALL BOATS

DIVING EQUIPMENT

A DAY'S OPERATION ON BOARD THE *Arcturus*

## INTRODUCTION

In fitting out the *Arcturus* for oceanographic exploration, so many problems, both old and new, were approached that it seems a pity not to give others the benefit of our experience in solving them. With this in mind I have endeavoured to give an account of our ship that is not only descriptive but critical.

This paper does not pretend to be a review of oceanographic appliances as it mentions only those devices used during the 1925

\* The photographs illustrating this paper were made by Ernest B. Schoedsack; the diagrams (except Fig. 15) were drawn by the Author.

<sup>1</sup> Contribution, New York Zoological Society Department of Tropical Research, No. 247.



Fig. 2. The S. Y. *Arcturus*. The ship is higher out of the water than usual, as the coal bunkers were almost empty when this photograph was taken.

expedition of the *Arcturus*. It represents, more than anything else, the answers to many questions, that we, as inexperienced oceanographers, had to solve.

We were indebted for much information both before and during the expedition, to the published descriptions of other oceanographic vessels, especially to the account of the *Michael Sars* given in "The Depths of the Ocean," by Murray and Hjort; to the accounts of the *Princess Alice* and the *Hirondelle*; and notably to the various papers relating to the United States Fisheries Steamer *Albatross*.

I take this occasion to express my gratitude to Mr. William Beebe for the many opportunities that he has given to me both before and during this expedition. I would also like to thank Dr. Charles J. Fish of the Bureau of Fisheries, for much valuable information and criticism.

During the expedition the sounding machinery and nets were in the hands of Mr. William Merriam and Mr. Jay F. W. Pearson, and we are indebted for the successful operation of these and many other devices to these gentlemen. The supervising of the dredging and dredging machinery was in the capable care of Chief Officer Robert G. MacLoughlin and Captain James S. Howes and we are thankful to them for the efficient functioning of their departments.

The changes to the ship were designed and supervised by Mr. Edwin Bennett, and I am grateful to him and to Mr. Charles C. Yates for many suggestions.

Although the modern science of oceanography is a mere infant of fifty-odd years, it has grown to such an extent that specialization in the solving of the many problems associated with the study of the sea has been the inevitable result. Superficially, oceanography can be divided into the physical aspect and the biological. But these two divisions cannot be entirely disassociated from each other, as in many ways they are closely united and problems concerning one are often intimately linked with the other.

The voyage of the *Arcturus* was dedicated mainly to the biological side, although no opportunity was lost to obtain physical data or specimens, such as soundings, bottom samples, temperatures at various depths, samples of water at different depths for the determination of salinity and density, and observations on weather, winds, currents and barometric pressure.



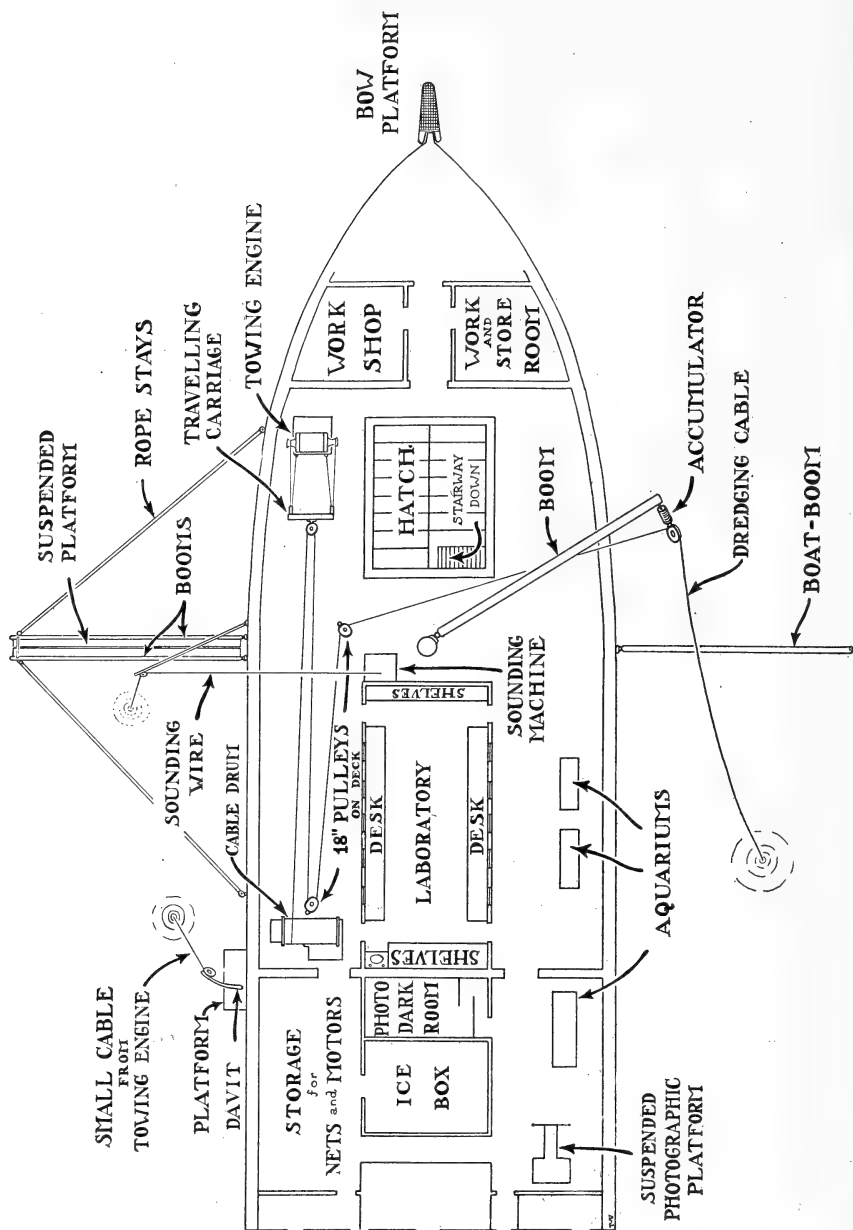


Fig. 3. Sketch showing the arrangement of the forward half of the main deck, also the method of leading the cable.

To change the *Arcturus* from a prosaic cargo-carrier to an expeditionary vessel capable of remaining at sea for long periods of time, required a great many alterations, not only in the special apparatus necessary for the exploration of the depths of the ocean, but in the construction of additional ice-boxes capable of holding six months' provisions, new cabins for officers, new dynamos to furnish the extra electrical current required, additional coal bunkers, and dozens of other things with which sea-faring men are acquainted.

To explain the changes found necessary and the actions of the various machines that were used during the expedition, the simplest method will be to describe briefly, first, the *Arcturus* and the apparatus that was installed on board, and secondly, in order to correlate the activities of machinery and personnel, a day's operations at one of the stations made during the expedition.

### THE SHIP

The *Arcturus* was built during 1919 in Bellingham, Washington, by the Pacific American Fisheries Company. She is a wooden vessel, fashioned of Oregon Pine, and built very sturdily to withstand the heavy seas and ice along the Alaskan coast. Her dimensions are as follows:—Length over all, 282 feet; Length between perpendiculars, 268 feet and 4 inches; Breadth, over the planking, 46 feet; Depth, molded, 26 feet; Gross tonnage, approximately 2,475 tons; and net tonnage, approximately 1,466 tons. She was launched as the *Clio*, but the Mariner's Star seemed a more fitting name for a vessel devoted to oceanography than that of the Muse of History.

The vessel has twin screws driven by two upright, reciprocating engines developing 750 horse-power each, which drive the ship at an "economical" speed of 6 to 8 knots, and a maximum speed of 9 to 10. For a vessel devoted to oceanographic work the possession of double propellers is an invaluable asset. Not only can the speed of the ship be varied to a greater extent, but the possibility of cutting a cable or tearing a net is practically eliminated when only the propeller on the opposite side of the ship from where dredging is going on is revolving.

The *Arcturus* is a coal-burning, steam-ship of the type known as a three-island, one-deck vessel. That is to say, she has three houses rising above the main or weather deck, a forecastle, a main

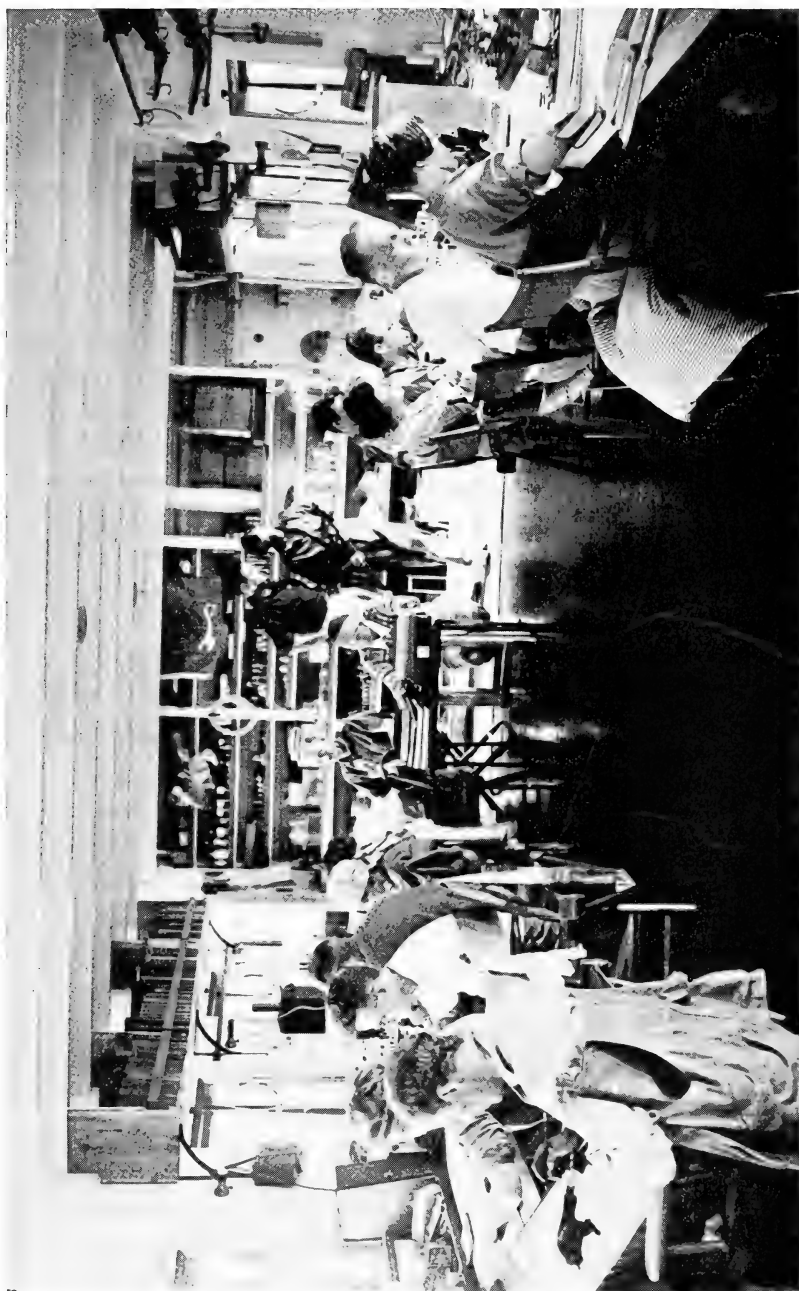


Fig. 4. The lower laboratory. View toward the after end.

house amidships, and a poop. The forecastle, originally the quarters of the firemen and sailors, was changed into two work-rooms, one for mechanical experiments and repairs, and the other for use as a store-room and for making plaster-of-paris molds of fish and other marine animals. The dispossessed mariners were transferred to the poop where adequate quarters were made available. This shifting of the crew to the after part of the ship was an arrangement that was ideal in every way, as it kept the entire forward half of the vessel free for oceanographic work and for the members of the expedition. The crew of the *Arcturus*, including the officers and two wireless operators, numbered thirty-five men.

The original midships island or house is the same outside as it was when the ship was launched, but many internal changes were made, especially on the main deck. This space,—the bridge casing, originally served as a coal-bunker. As the staff-members of the expedition occupied the officers' quarters on the bridge and boat decks, new cabins were constructed in the after half of this space, those on the starboard side being for engineers and those on the port side for deck officers. The forward half is now composed of extra ice-boxes, photographic dark-room, photographic gallery, space for aquariums, and storage space for nets and portable row-boat motors. (See diagram, Fig. 3).

The bridge-deck, immediately above the main or weather deck, contains the galley, crew's mess rooms, dining room for officers and members of the expedition, chief engineer's quarters and four cabins used by the staff. The next deck, the boat deck, contains seven cabins and the wireless room and hospital, the two latter being situated in a separate house aft. Above this deck is the navigating bridge and pilot house.

Immediately forward of this amidships house and above the original, second hatchway of the vessel, are the laboratories. The house in which they are contained is two decks high,—the floor of the lowermost one being a foot and a half above the level of the main deck. The second floor is at the level of the bridge deck. The lower laboratory, 36 feet long and 14 feet wide, was devoted to the examination and study of the various animals that were brought on board, and contained for this purpose suitable shelves and racks for chemicals and preservatives, vials, bottles and books. A 36-inch wide table placed at a suitable height for working extended along



Fig. 5. The forward hold showing the two levels where nets, specimens and extra supplies were stored.

both sides of the room. A sink was also provided in this room. Ample light was obtained by a series of large, square windows opening on either side, and access was by two doors at either end. In stormy weather, large, wooden shutters completely enclosed the windows and protected them from the possibility of being broken by waves.

The upper laboratory is similar to the lower but slightly smaller and with only a single door at each end. It was devoted to the library, artists' quarters, chart-tables and chemical laboratory.

Of the four holds into which the hull is divided, the first was used as an expedition store-room, where nets were hung and surplus supplies were kept. The second and at times part of the third were used as coal bunkers. The third and fourth holds had extra water tanks, while the remaining space in the fourth hold was used for miscellaneous supplies such as lumber, coal for the galley, etc. Entrance to the first and third and fourth holds was through the hatchways and down especially constructed stairways. The second hold, over which the laboratory is now built, could not be entered except through the coaling ports or the engine and boiler rooms.

Additional changes to the vessel made necessary by its new vocation resulted in the installation of a 30-foot boat boom, 6 inches in diameter, on the starboard side of the ship, in line with the foremast. This was used for tying up our small boats and launches whenever the ship happened to be in harbour. It was so constructed that it could swing in along the side whenever the ship was at sea.

A metal crow's-nest, capable of holding two or three people, was installed at the top of the foremast.

#### BOOM-WALK

On the port side in line with the foremast, was constructed a device invented by Mr. Beebe, which we christened the boom-walk. Two 30-foot booms, 6 inches in diameter were installed, spaced 24 inches apart, and hinged in such a way that they could be swung outward over the water from the side of the ship. A narrow platform was suspended by ropes, between and about 3 feet below these. The outer ends of the booms were supported by a cable which ran through a pulley fastened to the mast just below the crow's nest, and thence to the deck where it was fastened. Rope stays prevented backward and forward motion.



Fig. 6. The boom-walk and a net towing in calm waters. The pulley attached to the boom over the boom-walk, is part of the sounding machinery.

This glorified pirate's plank served many purposes. Almost all of our surface tow-nets were towed from the boom-walk, and as it was thus possible to have them far out from the side of the vessel, the water through which they swept was undisturbed by the wash of the ship. We usually kept the boom-walk horizontal, although the outer end could be lowered to the water's edge, or, in heavy weather, raised above the possibility of hitting the water. We found that it was seldom necessary to swing it in, even when the ship rolled heavily.

#### BOW-PLATFORM

Of almost equal importance was a small, iron platform, also a device of Mr. Beebe's, dubbed the "Pulpit," which projected forward from the prow and could be raised or lowered to the very surface of the water. This platform was very simply made of angle-iron, and had a grating floor of welded wire. It projected 6 feet forward from the bow and was 2 feet 6 inches wide at the after end, while the inmate was protected from falling out by a railing placed 3 feet 3 inches from the floor. It was supported by blocks and tackle from a davit built over the bow, and was held in place by guys leading back to the after end of the forecastle. Access to the pulpit was by means of a Jacob's ladder from the deck of the forecastle.

Hours were spent on this platform by members of the expedition while the ship was in motion and whenever rough seas did not occur. Surface organisms and sea-weed could be captured with the greatest of ease by using a long-handled net in the untroubled waters just ahead of the ship.

#### SOUNDING MACHINERY

Before the *Arcturus* sailed, attempts were made to procure a sonic sounding machine; but in the few months before we left it was impossible to have one built. Instead we acquired an electrically operated Tanner-Bliss sounding machine of the latest type, similar to those used for deep-sea work by the Coast and Geodetic Survey. It was installed on an elevated platform on the port side of the main deck just forward of the laboratory.

The apparatus consisted of a 26.9-inch diameter drum, 3.875 inches wide and with flanges 1.375 inches high, made of duralumin,



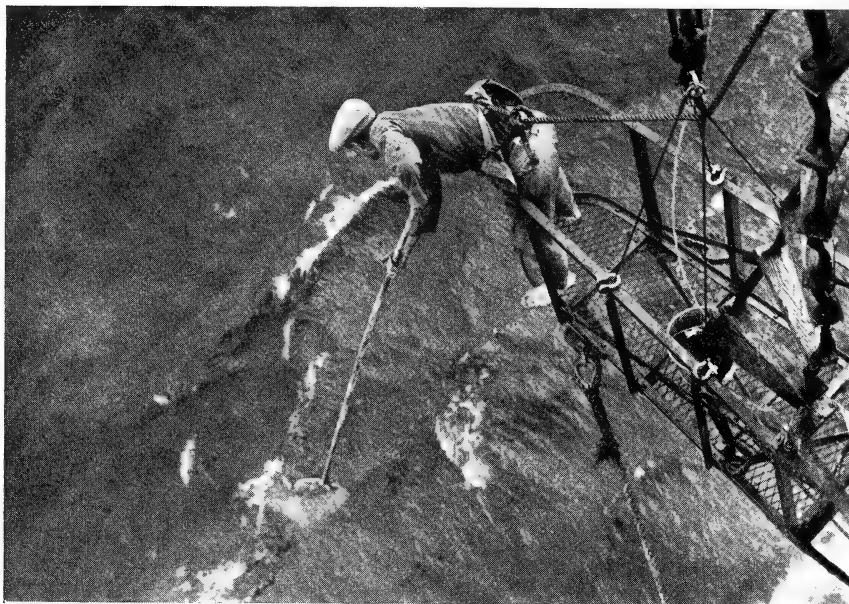


Fig. 7. Bow-platform. Usually the "pulpit," as the platform was called, was much closer to the water than this illustration shows. The rope about the waist was abandoned after the first week.

around which a maximum amount of 6 miles of steel piano wire, B. and S. gauge No. 21, was wound. This drum is connected with a 2 horsepower Diehl water-tight electric motor, the speed of which can be regulated by means of a rheostat. The clutch-brake is controlled by a single lever which moves the entire drum from side to side. When the lever is pushed away from the operator the inner portion of the rim of the drum is in contact with the brake and the wheel is held immovable; pushed half way over the drum is free and the wire can run out as fast as the weight can carry it; while if the lever is pulled toward the operator the inner rim of the opposite side of the drum comes in contact with a revolving wheel attached by a chain gear to the electric motor, and by this contact the wire can be reeled in.

This apparatus can be operated on small vessels by one man, but owing to conditions on the *Arcturus*, we usually had two or three,—one of whom read the meter wheel, recorded the time and saw that the wire was reeled on the drum correctly, while the second

governed the ascent or descent of the sounding apparatus. The third man usually attached the sounding weight, watched to see that the wire was straight up and down as it descended, and removed the surplus water from the wire as it ascended.

When in use the sounding wire was led from the drum up to a meter wheel, thence to a "tell-tale" or indicator,—a long metal rod with a pulley at its outer end. This rod was pivoted to a bar just above the drum and was supported by the tension of the sounding wire caused by the weight suspended at the end. The slightest cessation of strain on the wire allowed the rod to fall downward; so that when the sounding weight and tube struck the bottom and the tension on the wire ceased, the time of impact was recorded immediately and the amount of wire let out could be read off on the meter wheel.

From the "tell-tale" the wire passed outboard to a small pulley at the end of a boom, just above and to one side of the boom-walk, and thence into the water. (See Figs. 6 and 12.)

To avoid the possibility of kinking the sounding wire when it happened to come in contact with the bottom, the last 50 or 100 feet was replaced by the "stray-line," which was merely a piece of softer, more malleable wire. Other ships have used hemp rope for the same purpose.

At the end of the wire was placed the sounding rod or tube. Many models have been designed and used by different vessels; the one used during this expedition being the Sigsbee sounding tube. This tube has two purposes,—the support and release of the sounding weight and the capture of a sample of the bottom. It is a hollow tube 16 inches in length with a shaft at its upper end containing a tumbler or catch. The tumbler is held in place, as can be seen in the diagram, by a trigger-like device or pawl. When the pawl is connected with the sounding wire and under strain, its lowermost end fits into a notch in the tumbler. Thus the tumbler is held firmly in place as it holds the wire that supports the weight. (See diagram, Fig. 10 for the action of this part of the sounding weight.)

When bottom is struck and the tension on the wire is released, the pawl drops downward, releases the tumbler, and allows the wire and weight to drop off.

At the lower end of the cylinder is a valve which is kept closed by a spring and which has a plunger projecting below the lower end



Fig. 8. The sounding machine. To the right is the "tell-tale rod." The controller handle and electric motor are between the two figures.

of the tube. Impact with the bottom causes the plunger to open the valve, whereupon a small amount of the bottom is sucked or forced into the tube, and on coming away from the bottom, the valve closes and the specimen is brought to the surface. Other details of this sounding machine, such as the arrangement for allowing the water to escape from the inside of the tube during the descent, as well as the reasons for thin piano wire, light-weight drum and heavy shot, can be found in Tanner's "Deep Sea Exploration," U. S. Bureau of Fisheries Bulletin, Vol. XVI, 1896.

The sounding shots or weights weighed 35 and 75 pounds,—the 75-pound weights being used for soundings below three or four hundred fathoms. They are pear-shaped, conforming as nearly as

possible with stream line form, the lower end, as they descend, being the larger. The inner core is hollow, two inches in diameter, and fits around the sounding tube. At each side projects the outer portion of a nail,—20-penny nails being used in the 75-pound weights. These nails were cast with the shots and form a convenient projection by which the wire holding the sounding weight to the tube can be attached.

Practically the only mishap to machinery during the entire expedition was caused by the non-release of a sounding weight after it had hit the bottom. A sounding had been made in very soft bottom, and for some reason the weight persisted in remaining on the tube. Repeated attempts were made to release it, but without success. The wire was slowly reeled in, but the pressure exerted on the drum by the unusual additional weight was so great that the flange on one side of the drum broke off and pieces of metal were hurled about the deck.

Some of the soundings made during the expedition are among the records for speed as far as I know. At Station 105 in 2,803 fathoms, the entire sounding from the time the sounding tube left the surface until it came back with its sample, was taken in 51 minutes. This meant that the tube descended at the rate of 891 feet (148.5 fathoms) a minute, and ascended 542 feet (90.3 fathoms) a minute.

In shallow water of less than three or four hundred fathoms, we occasionally used mud snappers. These are heavily-weighted devices consisting mainly, of two scoop-like jaws. The smaller forms are made of a metal rod around which we placed a pear-shaped weight, and possess two small jaws on the lower end. The large mud snapper is shown in figure 9. It is a hollow tube, at the lower end of which are two jaws held together by a spring. Inside the tube is a rod, fastened at its lower end to the catches, projecting at the top and connected with the sounding wire. During descent the jaws are opened and held in place as shown. When the bottom is struck, the rod falls downward within the tube, thus releasing the catches, and the jaws are closed by the spring, retaining within their grasp whatever they have captured.

#### TRAWLING AND DREDGING MACHINERY

As the fisherman depends upon his line for pulling up his captured fish, so does an oceanographic expedition depend upon its

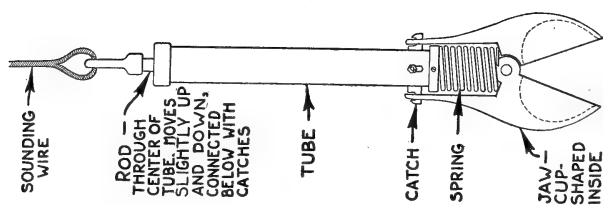


Fig. 9

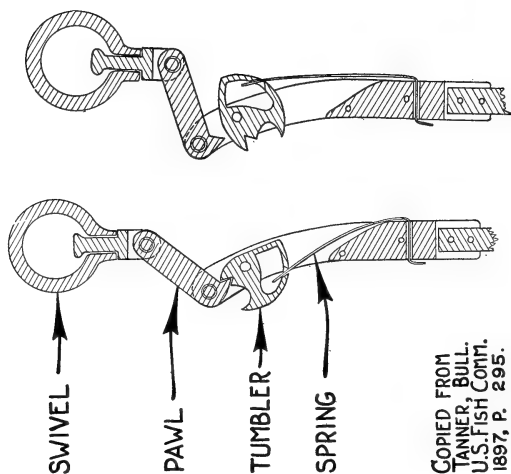


Fig. 10 Left

Right

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TANNER, BULL.  
U.S. FISH CONT.  
1897, P. 295.

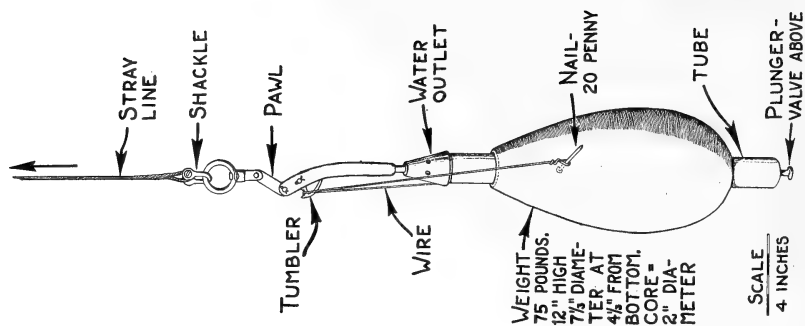


Fig. 11

Fig. 9. Large mud-snapper used on the expedition.

Fig. 10. Releasing mechanism at the top of the sounding tube. *Left*, held in place by the tension of the weight. *Right*, after the tube has struck the bottom and tension has been released.

Fig. 11. Sounding weight in place on the sounding tube and ready for use.

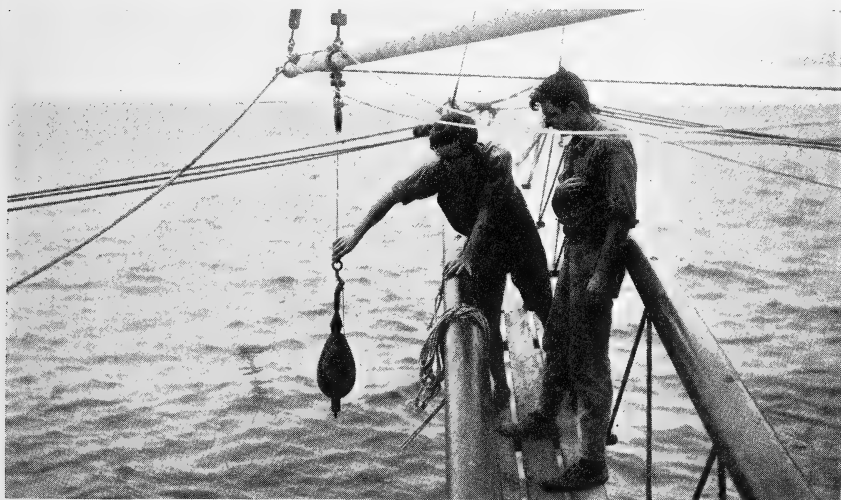


Fig. 12. The sounding weight and tube ready to go down.

line for pulling up whatever may happen to be caught. The line thus becomes an important, if not the most important piece of apparatus on board the ship. For admittedly one cannot bring back specimens from the deep if there is no means of getting nets and trawls down and of bringing them back.

For the work that we wanted them to do, the line, or, as it happens to be, the steel cable, had to be five nautical miles in length,—long enough to stretch up Broadway in New York City from the Battery to 79th Street, or up Fifth Avenue from Washington Square to 125th Street. Needless to say, this amount of heavy cable,  $\frac{1}{2}$ -inch in diameter, required special drums and machinery to handle it, and a few interesting engineering problems were encountered before the plans were completed and the engines made.

The problem of producing the machinery capable of carrying the cable and of taking care of the sudden strains that might occur when the vessel was trawling or dredging was placed in the hands of Mr. Spencer Miller of the Lidgerwood Manufacturing Company. After six months of constant operation we can say that the machines produced from Mr. Miller's designs were perfect<sup>1</sup>. No trouble of

<sup>1</sup> These machines have been described from a technical standpoint by Mr. Miller in the *Pacific Marine Review* for September 1925, and also in the *Bulletin of the New York Zoological Society*, Vol. XXVIII, No. 4, July 1925.

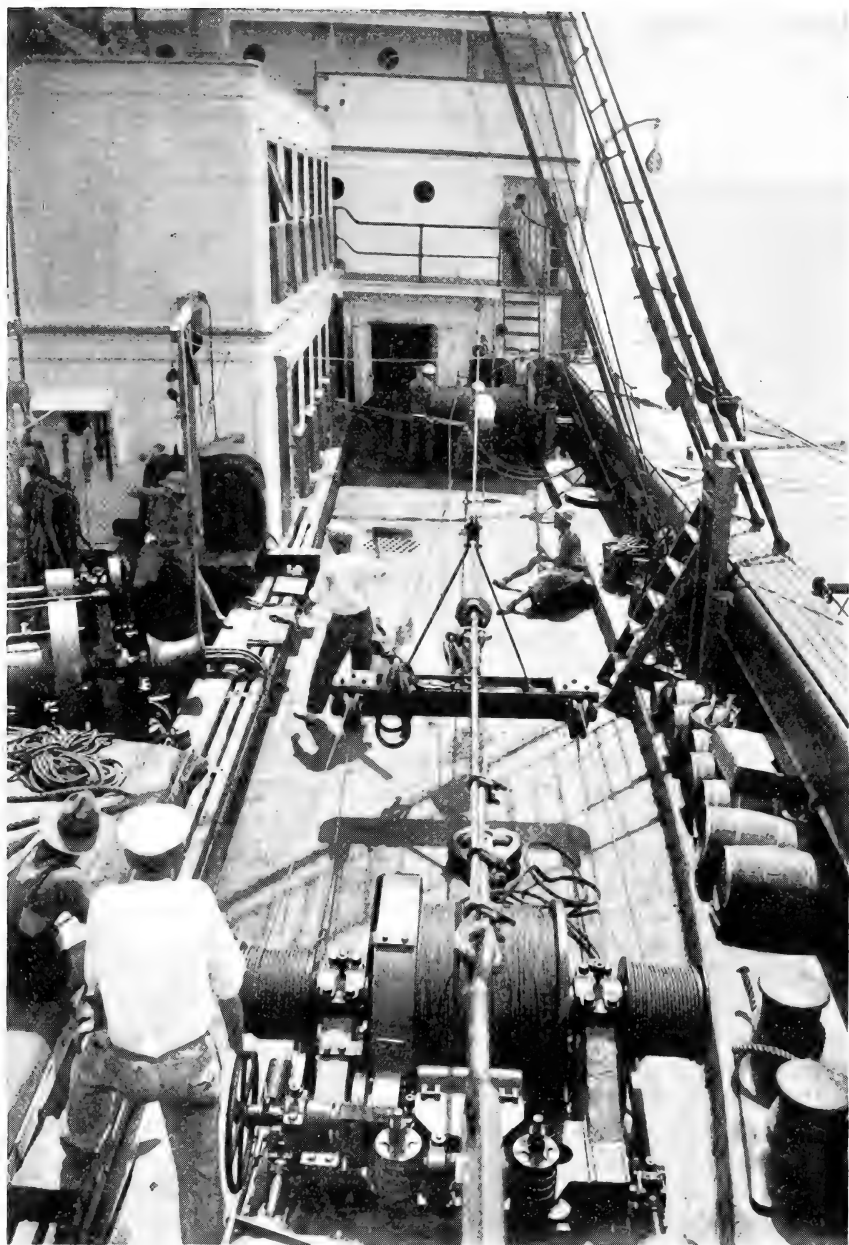


Fig. 13. Trawling and dredging machinery shown as the wire cable was being reeled in. Towing engine in the foreground. Surplus water is being beaten from the wire while in the background the cable is reeled onto the drum.

any kind was experienced during the voyage, and in emergencies the machines always worked as they should.

The trawling and dredging devices consisted of two machines. The larger engine, which held the main cable, had a drum with a solid steel core 10 inches in diameter, and with a steel flange at each end 48 inches in diameter and spaced 66 inches apart. Solid steel, carefully braced, was necessary to withstand the tremendous strains exerted both inwardly and to each side as the cable was wound under pressure onto the drum.

The drum was coupled by gears to a donkey engine which was controlled by a single lever, the upward movement of which let the cable out and the downward pulled it in. In the midway position the engine was stopped. The combined drum and engine were placed on the main deck just forward of the bridge on the port side.

The second machine was incorporated into the design to take care of possible jars and consequent breakage of the cable. It consisted of a small towing engine, similar to those used on sea-going tug-boats. These engines are made to maintain a constant tension and a constant length on towing cables when used between ships at sea. Thus when a vessel is being towed and a wave produces a violent tug on the tow line, the additional strain automatically activates the towing engine and a certain amount of line is paid out. As the strain relaxes the engine pulls in the line to its original length; thus the cable is kept from breaking and the tow from being uneven. How this principle was utilized on board the *Arcturus* will be shown later. This engine was placed on the main deck on the port side just aft of the forecastle, and in line with the main cable reel.

Suspended to a heavy cable between and above the two engines was a travelling carriage which could move up and down the deck from one engine to another. This carriage was connected by two cables, one on each side, to the towing engine. The lower half of each of these cables was firmly attached to the base of the engine, while the upper half was led to and wound around the small end drum of the engine.

When dredging on the bottom the cable was led, as shown in the diagram (Fig. 3) from the main drum to a sheave or large pulley on the travelling carriage and then to a pulley fastened to the deck just below the main drum. From here it went to another pulley fastened to the deck at the level of the main mast, and thence to a



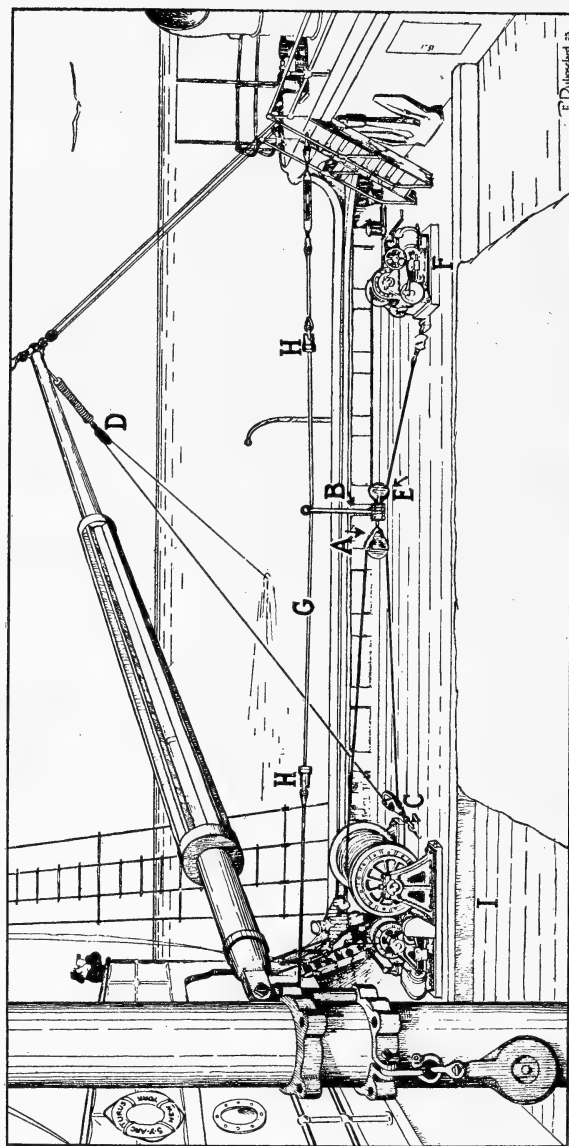


Fig. 14. Diagram showing the machinery used for operating the trawling apparatus. A, Pulley; B, Travelling Carriage; C, Pulley; D, Pulley at end of mast, connected with spring or accumulator; E, Pulley; F, Towing Engine; G, Cable from which travelling carriage is suspended; H, Stops, to prevent trolley from colliding with engines; I, Main Cable drum. The actual rigging of the cable was slightly different, as it was impossible to show the two sides of the ship in this drawing. From a pen drawing by P. Duboscard.

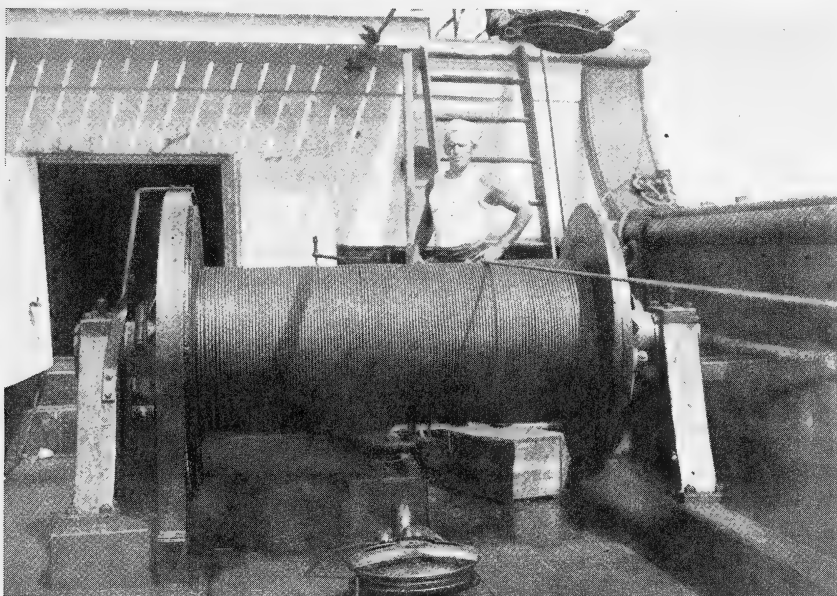


Fig. 15. The main drum holding the half-inch wire cable. About one-half the cable is being used for trawling.

pulley at the end of the starboard forward boom, from whence it passed into the sea.

The pulleys or sheaves were made of heavy steel and were eighteen inches in diameter. They were self-lubricating, as the inside of the wheel could be filled with oil which was gradually supplied to the axle. Larger diameter pulleys would have been better as the strain on the cable in passing around a sharp corner would have been considerably lessened by a larger sized wheel.

The pulley at the end of the boom was suspended from one or at times two large steel springs or accumulators. These accumulators were supposed to have a capacity of 10,000 pounds before the springs flattened. Their main reason for existence was to take care of sudden sharp strains on the cable, and in this way they co-operated with the tension apparatus in the towing engine.

The large cable on the *Arcturus* was  $\frac{1}{2}$  inch in diameter and formed of 6 wires of 19 strands each wound around a steel core. The solid core was deemed necessary because the wire was reeled in under full strain onto the drum. Other expeditions have taken much of the

strain off the drum by using a separate engine to haul up the cable, and afterwards winding it up on an independent reel.

During operations, one man was stationed at the main drum and another at the towing engine. The second man, however, was by no means necessary, as the machine when adjusted, operated automatically. If the dredge, as it was pulled along the bottom, happened to hit an obstruction of sufficient size to stop it, the immediate increase in tension was felt all along the cable. When the tension reached 10,000 pounds,—the reading being shown on a dynamometer, the strain on the cable transmitted to the towing engine through the travelling carriage caused the valves of the towing engine to open. This enabled the cables connected to the travelling carriage to pay out. The carriage was thus able to move down the deck, shortening the distance between its original position and the main drum, and incidentally allowing the wire which had stretched up and down the deck to pass overboard. The carriage moved at such a rate that the wire was able to go out at the same speed or a little faster than the ship went forward, thus reducing the strain on the cable or at least not allowing it to increase. The time the carriage occupied in travelling the 50 feet down the deck, thus allowing 100 feet of cable to run out, occupied from 10 to 20 seconds,—an interval of time sufficient to allow the man stationed at the main drum to open the valves and let out cable. As soon as the automatic towing machine gave way the officer on the bridge signalled to the engine room to stop the engines. In the meantime as the ship lost headway the cable continued to be paid out and the travelling carriage, as the tension was relieved, automatically moved back to its original position. When the tension relaxed, the paying out of the cable was slowed down and the winchman merely kept the line taut. If the dredge was still caught the vessel could be brought back over it and manœuvred until it was released.

Whenever necessary the towing engine could be disassociated from the travelling carriage and used as a simple reeling engine. For this purpose the central drum was provided with 15,000 feet of one-quarter inch diameter blue center steel cable. This cable was used day after day for taking temperatures and obtaining water samples, and for the vertical and vertical closing nets.

In order to preserve and prevent the cables from rusting after contact with sea-water, they were oiled after every immersion. In

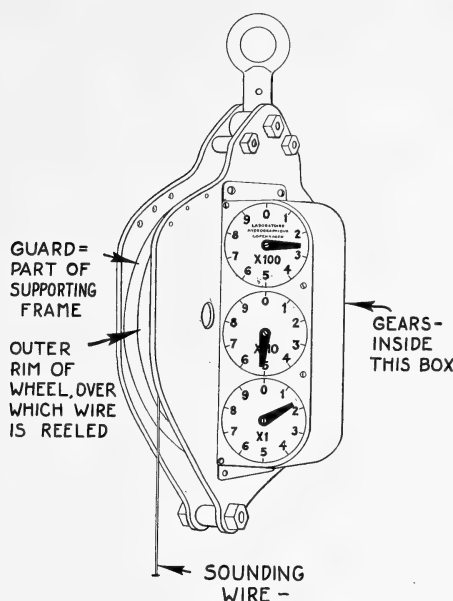


Fig. 16. Meter wheel.

addition to the oiling the members of the expedition took turns, two at a time, in pounding the cable with heavy wooden clubs before it was wound up on the drum. This procedure served a double purpose,—it gave us much needed exercise, and, more important, it removed the water from the interstices of the line. That this procedure was not as foolish as it sounds is attested by the excellent condition of the wire at the end of the expedition. Removal of the outer layer of solidified oil revealed shining steel wire as bright as the day it was made. Two hundred gallons of raw linseed oil were used on the cable during the expedition.

#### METER WHEELS, OR CABLE-MEASURING MACHINES

In all cases the length of the wire, whether sounding wire or dredging cable, was measured by passing it over a meter wheel.

The meter wheels used on the *Arcturus*, which were procured from the Laboratoire Hydrographique in Copenhagen, are made of a single wheel around which the wire travels, connected by gears to a series of dials which give the length in units, tens and hundreds of meters.

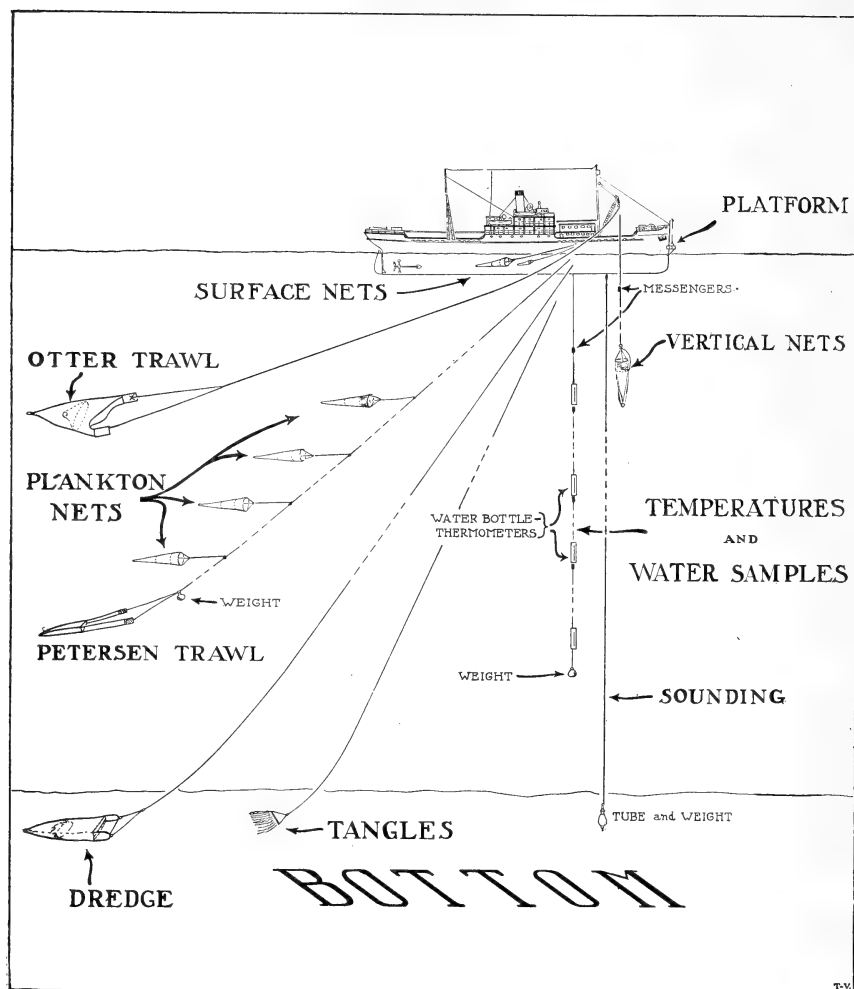


Fig. 17. Diagram of some of the devices used during the expedition.

Different sized wheels were used according to the size of the line. Caution was exercised to see that the cable made firm contact with the wheel in order that the registration would be correct. At the same time the wire could not be pressed down too hard, as grooves are easily worn into the metal and consequently errors in the length of cable might arise.

## TRAWLS

The Blake beam trawl was used for most of our bottom work. This is a sled-like frame of iron or steel behind which trails a bag or net. As can be seen in the illustration, the sled runners are the same on both sides. Consequently it does not matter how the dredge reaches the bottom; it will always land right side up. Some of the earlier deep sea dredges were so made as to land on one side only; if they landed on the other they captured nothing.

The runners of the Blake trawl are 4 feet 6 inches long and 2 feet high, and they are held apart by ten-foot bars. Six foot wide trawls of the same kind were used during the expedition.

The following measurements of the nets used to trail behind are taken from the specifications furnished to the makers: Beam trawl webs, with mouth 2 feet high and 10 feet wide, trailing for 20 feet. First 12 feet to be of 3 inch mesh, medium 30 thread. Bag at end to be 1 inch mesh 16 thread, and with a drawstring at the end. Mouth to be roped to 9 thread tarred manila rope. Bag to be equipped with a funnel.

Nets made of heavier thread would have been better, but the specified nets worked very well during our trip. Nets for the 6 foot dredges are of similar construction, but proportionately smaller. On Saba Bank, a coral reef in the West Indies, we used a trawl-net made of  $\frac{1}{2}$ -inch diameter rope. This worked successfully for a short time, but contact with the sharp edges of the bottom soon caused the ropes to fray.

For capturing the fish living on and near the bottom we successfully used otter trawls,—most of ours being somewhat smaller than those employed in shallow water by commercial trawlers. In addition to using them on the bottom we often towed them in mid-depths.

Otter trawls differ from beam trawls and dredges in that they have no iron sled in front to keep the mouth of the net open. The sled is replaced by two wooden boards placed some distance in front of the net and connected to it by ropes, or else fastened directly to the net. The two boards are attached to the towing cable by a rope bridle, the length of which in the larger nets used by us, was about 150 feet. Rigged in such a way (diagram page 73) the boards tend to pull apart as they are towed, and thus keep the mouth of the net open as widely as possible.

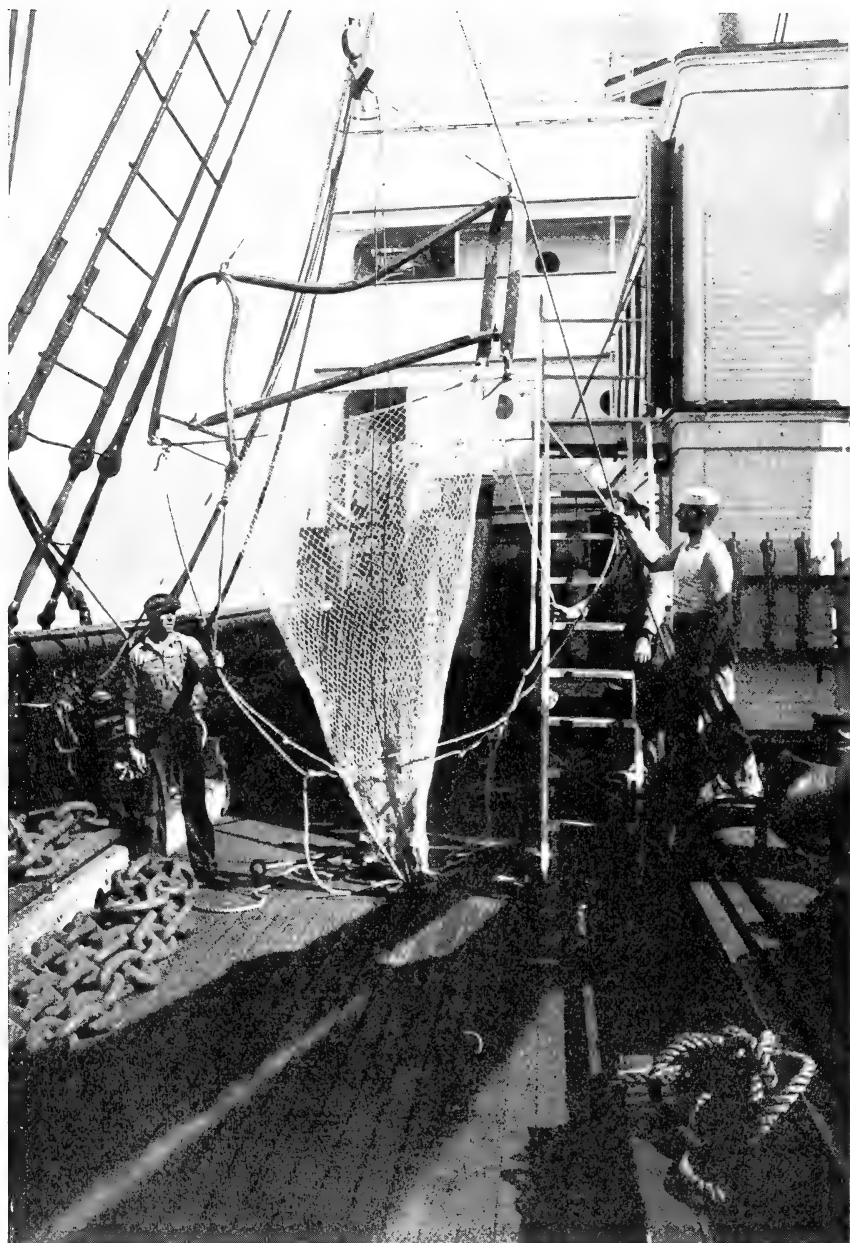


Fig. 18. A Blake beam trawl. This trawl, which is one of the ten-foot size, is shown after contact with a rock at the bottom of the Atlantic.

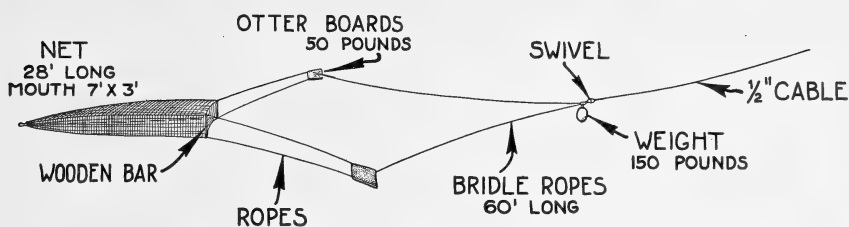


Fig. 19. Petersen trawl showing the arrangements of the otter-boards and bridle.

The trawls most commonly used varied from 10 to 50 feet across the mouth. A larger trawl, 80 feet across the mouth was lost the first time that it was sent overside. Specifications for the 50 foot net used by us are as follows:—50 feet wide from wing to wing. Mouth 40 feet wide. Net to be 45 feet long and to taper back to 10 feet, with drawstring at end. Netting 2 inch mesh, 9 thread medium. Mouth of net to be roped to  $\frac{1}{2}$ -inch tarred manila with 4 and  $\frac{1}{2}$ -inch cedar buoys 2 feet apart on top, three-sixteenths-inch galvanized chain on bottom.

The 10 foot trawls were for small boats. Their specifications were,—10 feet from wing to wing, 9 feet long, first 6 feet to be 1-inch mesh, 6 thread. Last 3 feet to be  $\frac{1}{2}$ -inch mesh, 6 thread. Barked and with drawstring at end. Mouth to be roped with 9 thread tarred manila. 4 $\frac{1}{2}$ -inch cedar buoys 2 feet apart on top. 2-ounce round leads 6 inches apart on bottom.

Petersen trawls were used constantly throughout the voyage, for the most part in the middle depths. They are easily handled and are rigged and operated in much the same way as the otter trawls. They are smaller, however, and the mesh is finer. The diagram shows the most important aspects of the Petersen trawl as we used it. The specifications for these nets as supplied to the net makers are as follows:—Petersen Trawl. 7 by 3 feet at mouth, 28 $\frac{1}{2}$  feet long, to go back straight for 20 feet and then taper for 8 $\frac{1}{2}$  feet with drawstring at end. Netting to be  $\frac{1}{2}$ -inch mesh, 6-thread medium barked. Mouth to be roped to 9 thread tarred manila. Four 4-inch buoys on top. Eight No. 6 seine leads on bottom.

#### TANGLES

During many operations tangles were attached to the end of the trawl. These were made of a bar of iron from 5 to 6 feet long



to which were attached chains, at the ends of which trailed long strands of frayed rope. On very rough bottom the tangles were used alone, and they brought numerous starfish, brittle-stars and other benthonic animals to the surface.

### TOW NETS

After five months of constant fishing with tow nets, we are convinced that the best type and size for general work on a ship such as the *Arcturus*, exclusive of quantitative studies, is the Michael Sars meter net. Their greatest advantage besides size, is in the coarse shrimp net collar which precedes the silk bolting cloth. This allows the water to strain through more rapidly and the net, consequently, captures a greater number of fish and other actively moving creatures that would otherwise be frightened away by the rush of water immediately in front of nets made entirely of bolting cloth. The same rush of water is felt, of course, with the Sars nets, but it is further back, and the animals apparently, are encompassed before they can escape. During the latter half of the expedition all of our tow nets with the exception of the diatom and small boat nets, were equipped with a netting collar.

On page 75 is shown a scale drawing of a Michael Sars meter net as used on board the *Arcturus*. A short explanation may help to clarify a few points in the figure. The net is cylindrical as far back at the end of the coarse OXX bolting or Dufour cloth. From here it tapers to the canvas collar that holds the plankton bucket or bottle.

The net is attached to the brass ring by means of overlapping flaps of canvas that are part of the canvas collar. The flaps are made so as to leave the bridle ropes free. They are folded over the ring and fastened by buttonholes securely sewed to the fabric. All seams are double sewed and taped,—the most suitable thread for sewing the silk portions being white cotton, size no. 60.

The larger nets were used mostly for towing beneath the surface. For surface work and for small boats we employed with a few exceptions half-meter nets.

The half-meter nets as we made them, had the bolting cloth portion similar to the specifications of the "Albatross" half-meter net. To this we added a shrimp net collar. Thus the net had a canvas collar attached to the brass ring, a half meter of shrimp net,

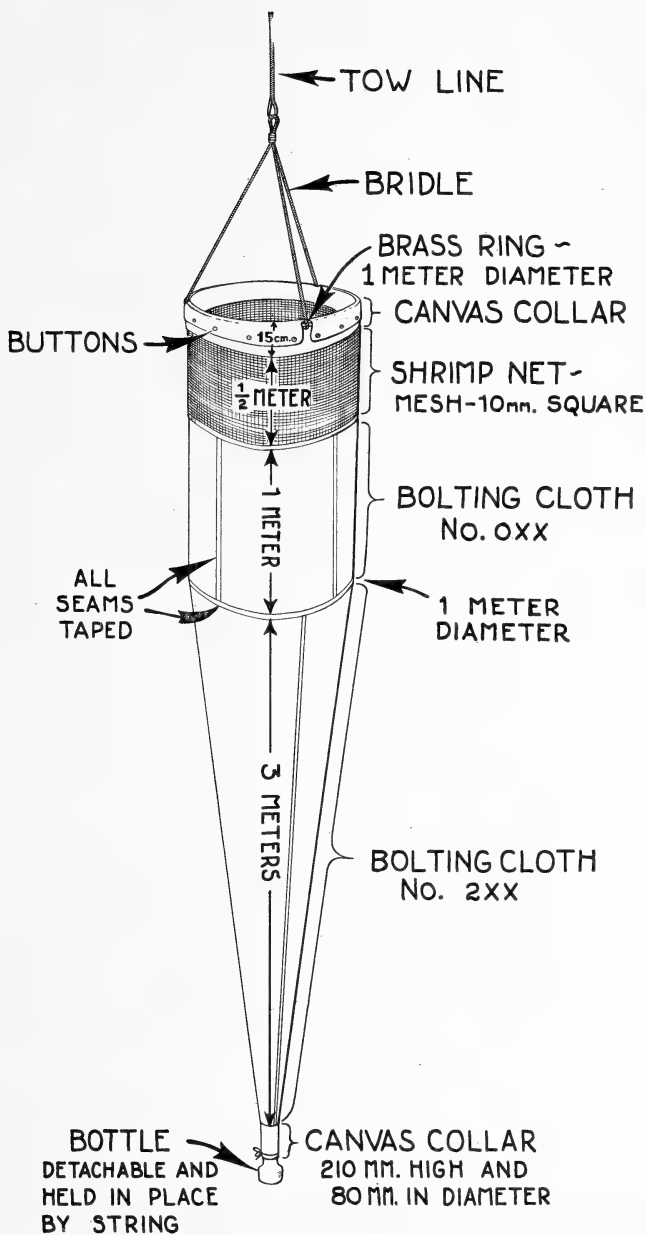


Fig. 20. A Michael Sars meter net as used on board the *S. Y. Arcturus*.

one meter of OXX bolting cloth and one and one-quarter meters of 2XX cloth. The bolting cloth, unlike that of the meter net, tapered from the half-meter diameter of the shrimp net collar, to the canvas collar at the end. This collar is 210 millimeters long and 80 millimeters in diameter. The collar at the forward end is of double thick canvas, two hundred and ten millimeters in depth.

Still smaller were the foot nets,<sup>1</sup> used for capturing diatoms and also for towing behind small boats. These are simply made, being 1 foot in diameter at the mouth, trailing three feet to the small end which is 2 inches in diameter. The collars are made like those of the larger nets. Those used for ordinary towing were made of 2XX bolting cloth while the diatom nets were of No. 20 standard bolting cloth.

The rings used for holding these nets were made of brass,—mostly because of its non-corrosive qualities. The rod for the meter nets was  $\frac{5}{8}$  inch in diameter, for the half meter  $\frac{1}{2}$  inch in diameter and for the foot rings  $\frac{5}{16}$  inch.

Because of delays in manufacture, the metal plankton buckets that are fastened to the ends of the nets, did not reach the *Arcturus* before sailing, and although they chased the ship from port to port, they never did reach us. In their place we used pint mason jars which fitted perfectly into the collars. The possibility of breaking was eliminated by covering the jars with heavy burlap and inserting them into drum-shaped cigarette tins, which had contained 100 cigarettes.

When in use the neck of the bottle was inserted into the net and held in place by linen tape, which was wrapped about and tied in a bow knot. This device had advantages in being inexpensive,—mason jars and cigarette tins abound,—and in being efficient. As a net came up out of the sea, a pull on the string released the bottle, and the contents could be emptied into pans with ease. The animals were not damaged, as in some other plankton bottles, by contact with rushing water.

The canvas used on all the tow nets was 8-ounce duck. The webbing collars were in all cases made of 6-thread medium, the mesh  $\frac{1}{4}$  inch square meshed and barked.

<sup>1</sup> It is unfortunate that no single system of measurement is in use in oceanography. Meters and millimeters conflict with fathoms and feet and inches, and there is no immediate prospect of abandoning one group or the other. Hence the use of whatever measurement happens to be convenient.

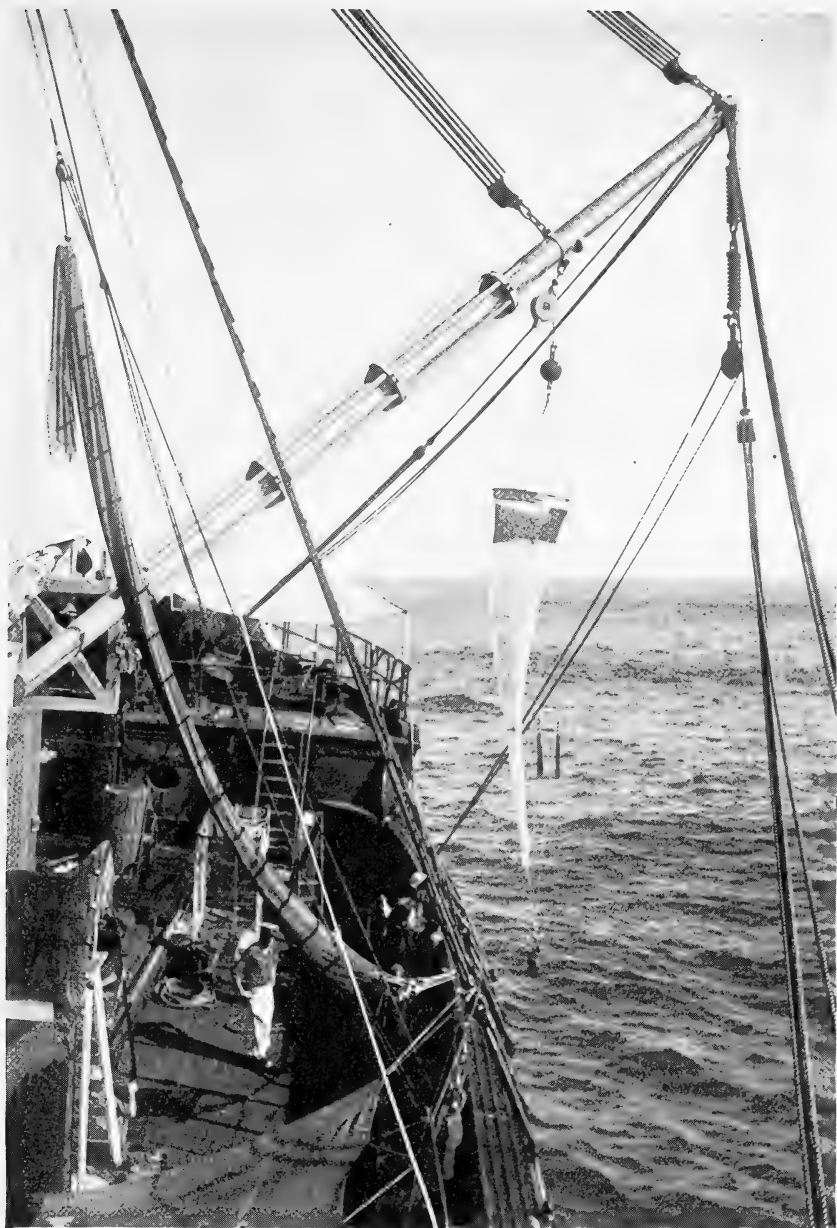


Fig. 21. Closing net of the Tanner type about to descend. The dark net hanging from the rigging to dry is a Petersen trawl.

Bridles for all these nets were made on board by the sailors. They were made of three ropes. One end of each was spliced to the brass ring while the other ends were formed into a loop at the top, into which, on a few of our nets, we placed a metal thimble. Thimbles were by no means necessary, as a rope loop will stand practically all the strain that it is likely to meet. Steel cable has been used on many ships for bridles.

#### VERTICAL NETS

For quantitative work with vertical and vertical closing nets we used the Tanner and the Nansen closing nets. The Tanner was used during the early part of the expedition, but was soon superseded by the Nansen.

The first few hauls in the Sargasso Sea demonstrated that in regions where the fauna was scanty the half-meter standard, vertical net did not "fish" enough. Meter nets were rigged in their place and we eventually employed them exclusively. Closing net and vertical hauls were made with both the large and the small cables.

The closing device used on the *Arcturus* was one that is employed in coastal waters by the U. S. Bureau of Fisheries. For work in deep water, however, the apparatus shown in the Pub. de Circonstance, Inter. Cons. Explor. de la Mer is undoubtedly the best device to use.

This instrument is attached to the end of the cable and the net is then fastened to it, first by means of the permanent fastening which holds the throttling rope, and second, by means of the rope which supports the net as it is pulled through the water and which is held in place by the trigger. The diagram illustrates how the net is closed by means of the messenger which is slid down the cable from the surface, tripping the trigger and releasing the supporting rope, after which the net throttles itself and is brought to the surface.

#### ATTACHING NETS

When dredges, otter trawls and Petersen trawls were used, the bridle was attached to the thimble at the end of the cable by means of a shackle. A heavy steel swivel was always inserted between the end of the cable and the shackle, else the twisting of the cable as it descended was very likely to foul the net.

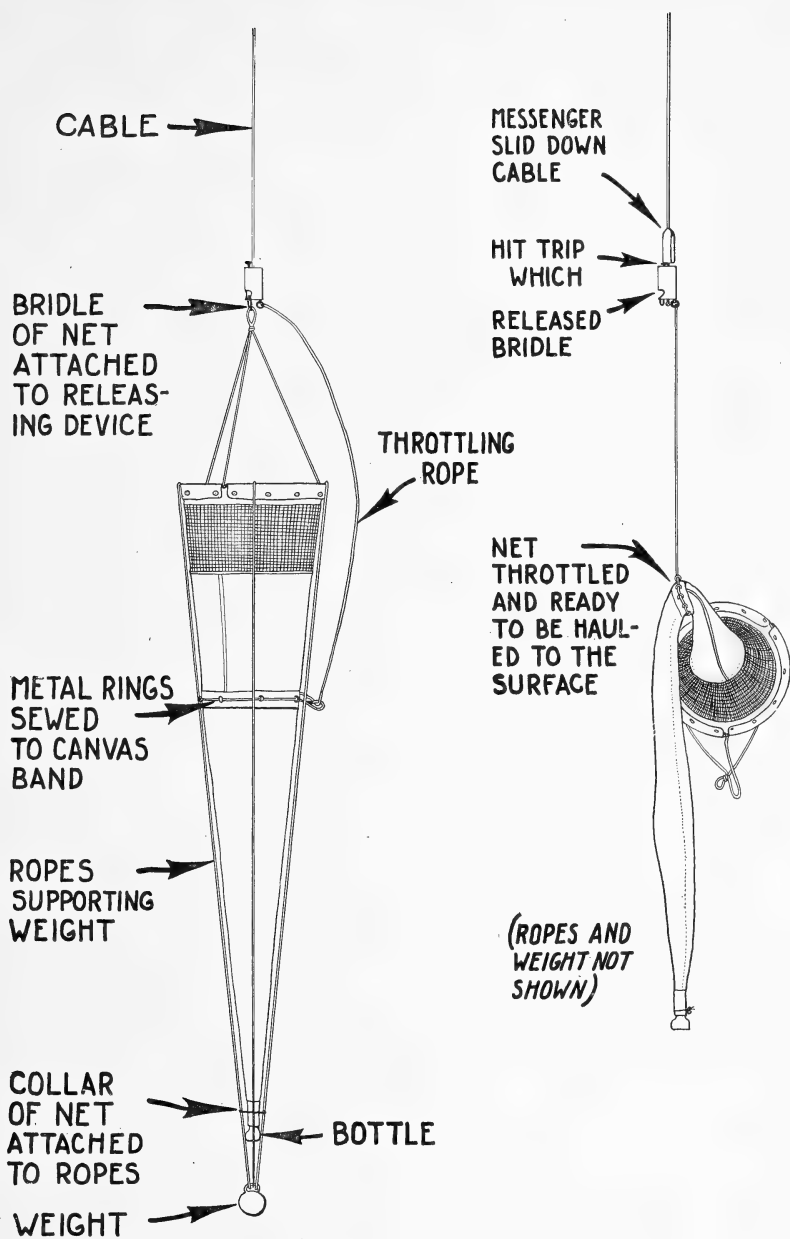


Fig. 22. Nansen closing net as used on the *Arcturus*. *Left*, net as it descended. *Right*, net after messenger slid down the wire, ready to be brought to the surface.

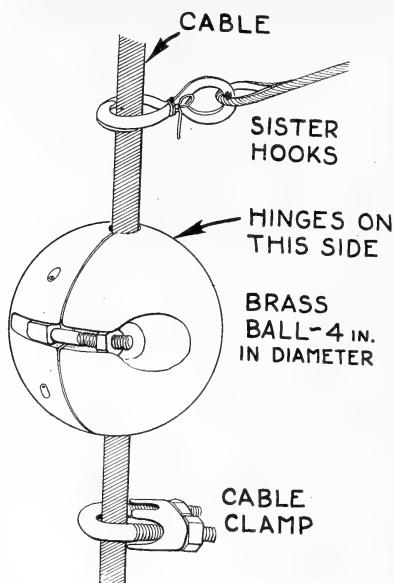


Fig. 23. Devices used to attach nets at various points along the cable.

Attaching the plankton nets to the cable at places other than the end presented a different problem. At first we used cable clamps, fastening them firmly to the wire, and then attaching the net by means of a bar fastened over the prongs of the clamp. A few experiments showed that this would not do as the nets became tangled about the cable. We then adopted the brass ball used for this purpose by the *Michael Sars*. We modified the design as shown on page 49 of "*The Depths of the Ocean*," by having the bolt, which tightens the ball in place, made as a part of the ball. After the ball was fastened to the wire, the net with its 6 to 15 foot leader was attached to the wire by clamping the sister-hooks about the cable above the ball. This permitted motion of the net in any direction and worked perfectly during the entire cruise.

With the exception of the Blake trawls, all of the nets were pulled downward into the ocean by means of a 150-pound ball which was fastened to the end of the cable.

It is advisable to have an abundance of cable-clamps, shackles and sister-hooks of various sizes on hand. They were constantly in use on board ship and were invaluable for attaching pieces of apparatus and for making temporary repairs.

## MISCELLANEOUS FISHING GEAR

Gill nets were on board but were seldom used. About the Galapagos Islands we found that too much time was wasted in removing sharks and disentangling snarls from the nets to warrant their continued use. They were of linen, in various sizes ranging up to 300 feet by 15 feet, 6-inch mesh and made of 16-3 cord.

Seines ranging from 29 foot bait nets to 300 foot nets were part of the equipment. Nets of 70 to 80 feet long and from 8 to 10 feet deep, of 1-inch mesh were most efficient for work along beaches. Nets of this size can be easily handled by two men unless they are pulling in surf. It is most important that each seine be furnished with a bag.

Dip nets of various sizes and shapes were indispensable. Long-handled ones were especially useful, especially on a ship with high sides such as ours.

Hand harpoons of different makes were used occasionally. In addition we employed small, hand harpoon guns which discharged a harpoon and carried a small rope with the weapon.

The *Arcturus* was amply supplied with fishing tackle such as hooks, lines, sinkers, etc. Materials for set lines were also available.

Electric lights capable of being submerged were used to attract fish and other organisms within range of the dip nets.

One of our submersible lights was made of an ordinary flash-light encased in a heavy steel tube with an especially strong glass window. This was placed within traps and sent below the surface, where, it was hoped, luminescent fishes would be attracted to the traps and caught.

Many kinds of traps from eel and lobster pots to large wire contraptions of various kinds, were on board and were used whenever possible.

## THERMOMETERS AND WATER-SAMPLE BOTTLES

The combined thermometer-water bottle used during the expedition was the Greene-Bigelow model, designed by Dr. H. B. Bigelow and Mr. J. V. Greene of the U. S. Bureau of Fisheries. The diagram illustrates the various parts of this machine and how they function. As can be seen, the device consists of three parts,—the reversing thermometer, the water bottle, and the releasing device at the bottom, all three of which are activated at the same time by the messenger which slides down the cable.



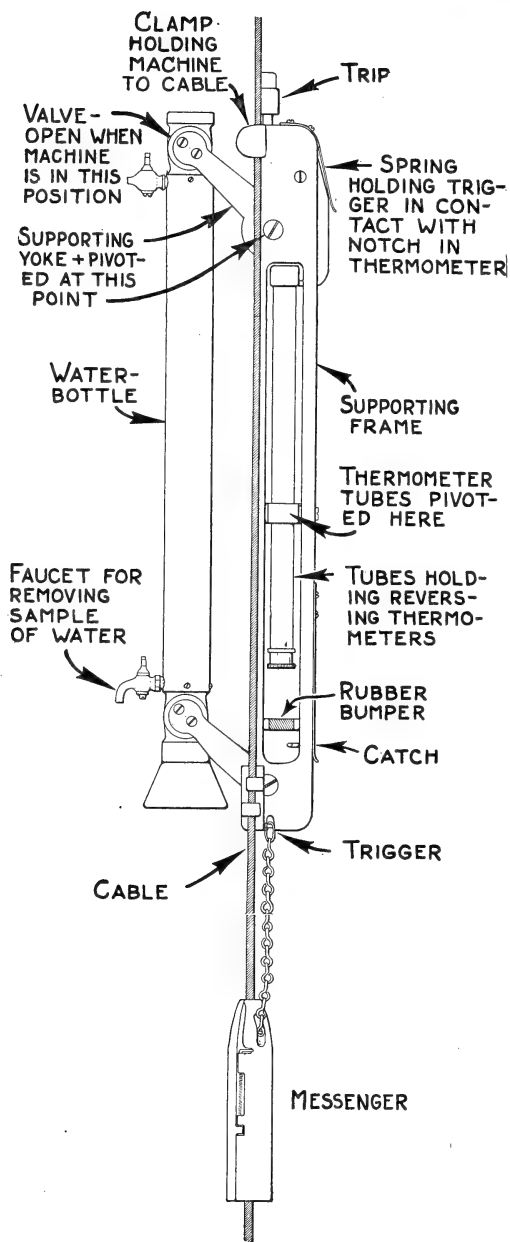


Fig. 24. Diagram of thermometer water bottle ready for descent.

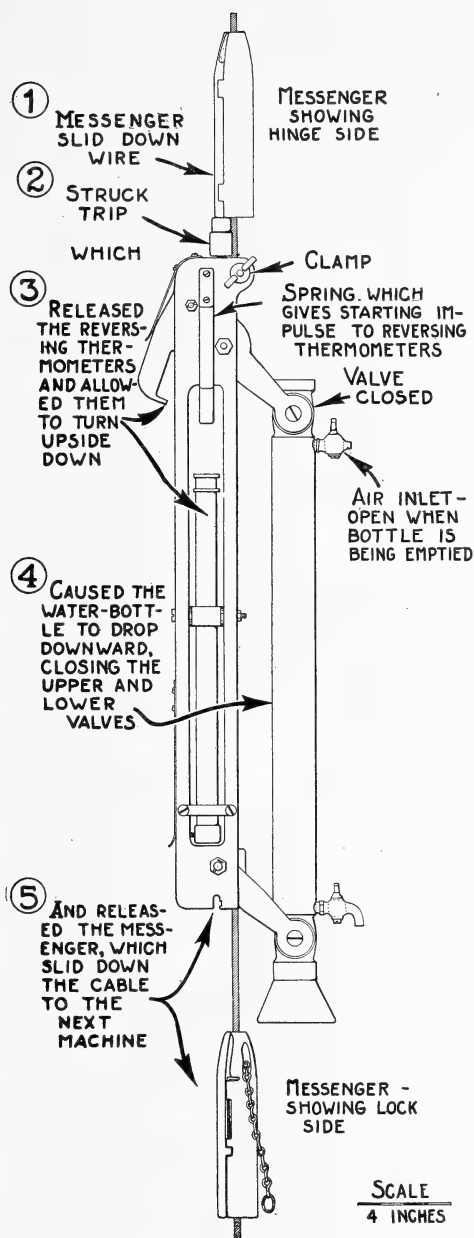


Fig. 25. Diagram of thermometer water bottle ready for ascent.

Temperatures and samples of water were taken with the ship stationary and with the thermometers fastened to the one-quarter inch cable attached to the drum of the towing engine. The cable was led over a meter wheel so placed that the winchman could easily read the dial, and thence aft and outboard to a davit placed over a platform suspended just outside the bulwarks on the port side of the ship.

When all preparations were completed, a weight of one hundred and fifty pounds was attached to the end of the cable and lowered to ten or twenty feet beneath the surface. A thermometer was then clamped to the wire and allowed to descend. Additional thermometers were fastened to the cable at predetermined distances,—all of these, with the exception of the bottom one, having a weight or messenger attached to their lower ends. The messengers are heavy, hollow, metal cylinders, made in two halves and hinged so that they could be clamped about the cable at any time or place.

After the thermometers had been sent to the various depths at which temperatures were desired, they were allowed to remain there for three or four minutes in order that the mercury might adjust itself to the temperatures at that depth. A messenger was then clamped about the cable and allowed to slide down. As it hit the tripping device at the top of the first thermometer it simultaneously accomplished three things. It disengaged a catch which allowed the water bottle to drop downward, thus closing the upper and lower valves and enclosing a sample of water. With the same motion the thermometer tubes were released and they swung about in a vertical arc so that their bulbs were uppermost. The messenger, which hung below, was released at the same time and slid down the wire until it struck the next instrument where the entire operation was repeated. And so the process went on until the last thermometer was tripped, after which they were brought to the surface, the temperatures recorded and the samples of water removed and stored in citrate of magnesia bottles.

Two thermometers made by Schmidt, and of the usual deep-sea reversing type were used at each level, so that by checking one against the other the possibility of error was extremely small. The thermometer is enclosed with an ordinary thermometer in a heavy glass tube capable of withstanding the immense pressure in the deeper layers of the ocean. These instruments are made with a constriction in the tube, just above the bulb. The column of mercury,

when the thermometer is in the normal position with the bulb down, extends above this constriction, and the amount that it extends depends, of course, upon the temperature. When the thermometer is reversed the mercury breaks off at the constriction and the detached portion drops down to the opposite end from the bulb. The height of the detached stem of mercury can now be read off on the engraved scale. This reading represents the temperature at whatever depth the thermometer was reversed.



Fig. 26. Water bottle coming to the surface showing messenger resting on the wire above the machine.

The ordinary thermometer is to record the temperature at the moment the reversing thermometer is read, as corrections must be applied to the temperatures recorded, owing to the slight expansion or contraction of the glass, and the consequent slight difference between the actual temperature and that recorded.

The thermometers were examined every time they were sent down to make sure that the mercury contained no bubbles and the machines were oiled every second or third time. During the first few weeks one or two failures of a thermometer to reverse were laid

to lack of lubrication. The few minutes that we spent in oiling them were well repaid. Because these devices are subjected to low temperatures, it is vital to their efficient operation that the lubricant have a low congealing point. Otherwise the machines when lowered will "freeze" and neither thermometers or water bottle will function.

After use, the reversing thermometers must be restored to their original position with bulb lowermost, and the entire device kept upright. If droplets of mercury remained detached from the main body, the thermometer was gently tapped until they connected.

Ordinary protected thermometers were employed for taking surface temperatures. These were taken by the officer on the watch, who threw a weighted bucket into the sea, and scooped up a sample of water, in which the thermometer was immersed.

Sigsbee water-bottles were included in the equipment, but were not used during the expedition.

#### LABORATORY EQUIPMENT

Ideas about laboratory equipment will differ on every expedition. During our trip we had the satisfaction of knowing that our supplies were ample, and that we had foreseen every need.

Our laboratory work, after the animals had arrived on board, divided itself into two parts,—first, the study of the animals in all its phases, identification, description, photographing, painting, etc. and secondly, fixing and preservation.

The study and identification necessitated a fair-sized library containing all the standard oceanographic reports, and instruments for manipulation of the organisms. Five binocular microscopes, two monocular high-power and three dissecting microscopes, besides many pocket lenses and lens holders, were in constant use. Correlated with these was a large assortment of glass slides and materials for making mounts. Drop cells are invaluable and were used for mounting the many organisms that were too thick to mount under an ordinary glass.

Other indispensable supplies were large assortments of dissecting scissors, dissecting needles, and forceps of different sizes. All our instruments were of ordinary manufacture, and nickel plated. With-

in a few weeks we were soon aware of the fact that salt water plays havoc with such instruments and that they ought to have been made of rustless steel.

Glass dishes of various sizes are indispensable. We found that dozens of Stender dishes 2 inches in diameter and 1 inch high, and 4 inches in diameter and 2 inches high were necessary. Larger jars 12 inches in diameter, and 3 to 4 inches high were extremely useful. Glass jars, known as household jars, 10 to 12 inches high and 8 inches in diameter were in constant demand for holding plankton.

Metal, white-enamelled pans, 16 inches long by 10 inches wide and 2 ½ high were always on deck to hold the plankton as it was removed from the nets. Higher sided pans might be advisable, except that the plankton is more easily studied and the delicate specimens can be removed with greater ease from the lower-sided containers.

Wooden and galvanized-iron wash tubs served a similar task in retaining the contents of the dredges before and during study.

Suitable paper labels were made for labelling each specimen or group of specimens. These varied in size, depending upon the containers. Most of them were small, and the details were filled in with waterproof India ink, which was thoroughly dried before immersion in the preservative. Oval zinc labels stamped with a number were attached in suitable places on the larger specimens. The zinc, however, corrodes in formalin, and is not especially suitable in that liquid.

Artists' supplies of all kinds were on board.

For killing and fixing we had ample quantities of the usual chemicals used for marine animals,—mostly those given in Lee's "Vade Mecum." Preservation of the larger forms was in the usual strength alcohol or formalin.

Proper sized containers are of great importance for preservation. If possible, each animal, especially among the crustacea, ought to be in a separate container. The possession of a single perfect specimen with appendages intact is worth more than dozens of imperfect ones which are inevitable when large numbers thrown together.

Because of this, the *Arcturus* carried vials and bottles and jars of all sorts and sizes. Homeopathic vials with the finest quality corks, (a consideration of great importance) of 1, 2, 4, 6 and 8 dram sizes were employed. Larger than these were the 4 and 6 ounce

wide-mouth bottles. Especially useful for elongate fish were test tubes 6 and 8 inches long and  $\frac{3}{4}$  to 1 inch in diameter and also glass jars 8 inches long and 2 inches in diameter. Glass-topped mason jars of pint and quart sizes were on board in large quantities. An assortment of these vials and jars placed in racks was always on hand in the laboratory.

Earthenware jars of 5, 10 and 20 gallon capacity were used for the larger organisms. The tops of the five-gallon jars were held in place by a spring clip, while those of the 10 and 20 gallon containers merely rested on top and were held in place by their own weight. Even in fairly heavy weather, if the crocks were not too full, but little preservative was lost. Still larger organisms were kept in 50 gallon barrels.

Most of our specimens were preserved in 75 per cent. alcohol or in 4 to 5 per cent. formalin. If necessary, we resorted to stronger or weaker grades. We always kept an alcoholometer close to the alcohol containers, especially when fresh specimens were immersed.

For the purpose of making casts and models we had an abundance of plaster of paris, beeswax and other casting materials.

#### AQUARIUMS

The quietness and greenness of a balanced aquarium was never attained by the fish tanks of the *Arcturus*. Owing to the rolling of the ship, the water in our aquariums was in too constant motion to allow anything to balance. Nevertheless, we were able to keep alive for months such interesting things as star-fish, serpent stars, barnacles and many different species of fish.

For observational work with salt-water fish we required an easily handled tank, not too large. Knowing that the majority of fish that we would have would seldom be over nine or ten inches long and generally much less, we had constructed a series of thirty aquariums, the largest being 23 inches long by 17 high and 17 deep, the remaining ones being slightly smaller. In addition we had forty aquariums 10 by 6 by 6 inches, a size that is practically indispensable.

All these tanks were constructed of galvanized iron, the glass being fastened in such a way as to allow the least amount of cement to come in contact with the water. All four sides and the bottom were made of glass, the bottom glass being much thicker than the sides.

The aquariums were placed on a three-tiered platform in the forward end of the starboard side of the bridge-casing. The two upper tiers had a rim 2 inches high about the outside and were lined with galvanized iron. Drain pipes led away from these troughs to the scuppers and thence overboard.

A constant stream of water was supplied to these tanks from pipes and faucets suspended above them. In order that the aquariums did not become too full, a triangular piece was cut out of the glass in the upper corner of one side.

Thus we had aquariums supplied with fresh salt water and with an outlet that allowed the surplus water to drain away. More complicated apparatus and more expensive materials might have been used, but for simplicity and efficiency this arrangement is excellent, although a few improvements are necessary.

Future changes to this group of tanks ought to consist of a new system of water supply. On the *Arcturus* the salt water came from the ship's pumps, and while this was adequate for the time being, it is insufficient for future operations. The best arrangement, as has been demonstrated in other laboratories, would be to have a pump or duplicate pumps, preferably electrically operated, made entirely of hard rubber so that no metallic substances could contaminate the water. From these pumps the water ought to be led through lead pipes and hard rubber faucets to the aquariums.

For larger fish the ship's carpenter constructed wooden tanks, approximately 7 feet long by 4 high and 2 deep. The front of these tanks was at first made of sheets of plate glass 6 feet by 3. We found, however, that glass of this size broke very easily when in a wooden tank on shipboard and we were forced to use a maximum size of 3 feet square. Apparently, it is not possible to build a wooden aquarium that will not give in some direction when the ship rolls. And as glass is not sufficiently plastic to withstand the strain, it gives way.

For the observation at close hand of the smaller fish and other animals we found that filter troughs used for microscopic purposes, answered our requirements. They vary in size and those we found most valuable were from 1 to 2 inches thick by 4 inches high and wide. They are indispensable for photography, as their plane sides give no false reflections when artificial lights are flashed upon them.



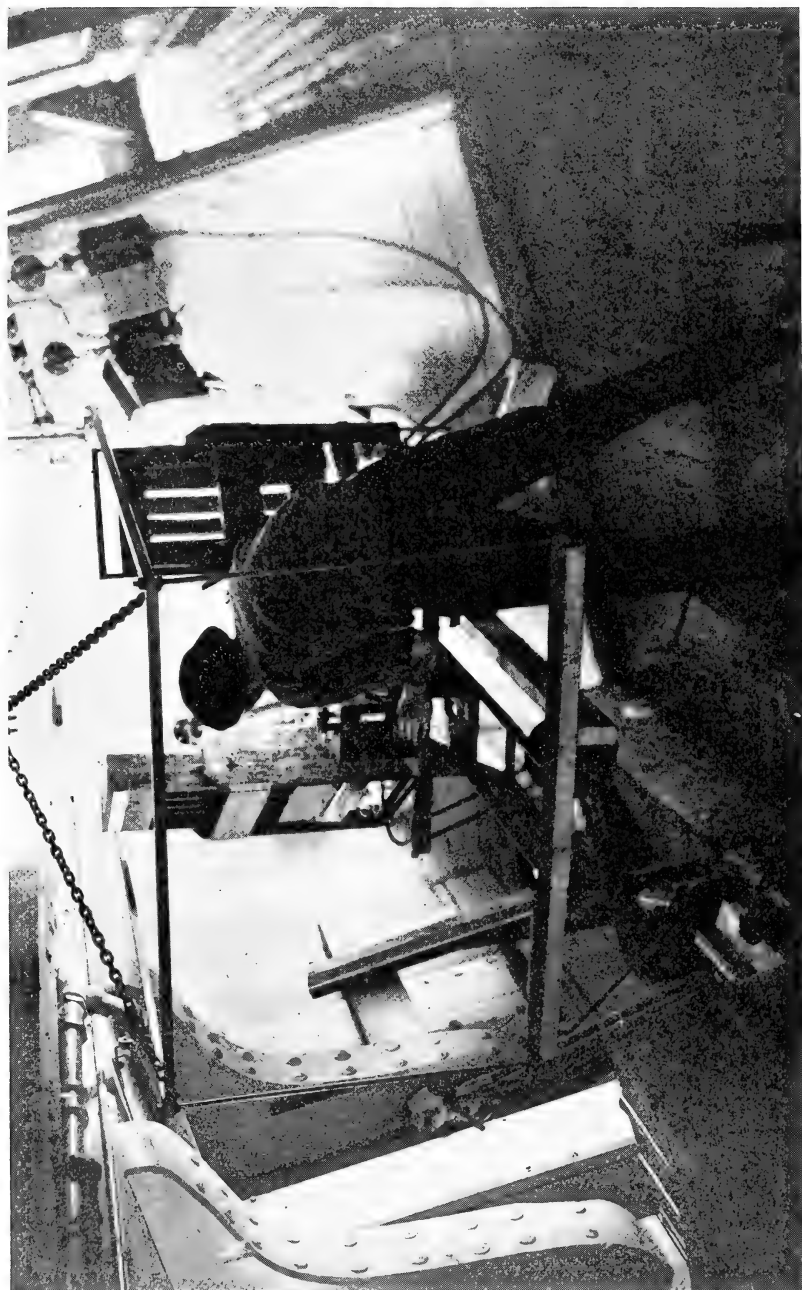


Fig. 27. Photographic laboratory showing the suspended platform.

## PHOTOGRAPHIC EQUIPMENT

Photographing marine animals in aquariums filled with water is a fairly simple matter when the aquarium can be placed on a firm base. But when the stablest ground is a rolling ship, never at the same level for a second, the problem of obtaining photographs of the organisms brought up from the deep becomes somewhat complicated. To add to our difficulties, many nets containing interesting animals are brought to the surface at night. So the problem resolved itself into the production of some method whereby both the roll and pitch of the vessel could be compensated and of some way in which sufficient light could be obtained by night or day not only for still photography but also for motion pictures.

These difficulties were solved by the erection in the bridge casing, on the starboard side, of a suspended platform, fastened to the ceiling by a universal joint, which allowed it to swing forward and backward or to either side. Heavy weights were added and the result was a platform that kept its equilibrium whether the ship rolled or not. To watch an aquarium filled with water resting on this device was to doubt one's eyes, as the impression gathered was that the ship stayed motionless while the water went off at unaccountable angles.

On the platform were placed two units of Cooper-Hewitt mercury-vapour lamps, each unit containing two U-shaped tubes thirty inches long. The units were fastened in such a way that they could be moved horizontally through an arc, and if necessary, tipped forward. These precautions were necessary to avoid the possibility of reflections on the glass of the aquariums. Convenient switches made it possible to use any one or all four of the tubes or any combination. In addition a small arc lamp was used. This could be moved to various parts of the platform, so that its beam could be directed on to an object from above or below or from the side.

The objects to be photographed were placed on a movable stage, situated so as to be flooded with light from the lamps. The cameras were also on a movable stage which could be run backward or forward. The arrangement, altogether, was a very satisfactory one and many photographs were taken on it during the expedition.

Future oceanographic expeditions might improve upon this arrangement by building a room suspended in the same manner,

and either heavily weighted to maintain its horizontal position or else gyroscopically controlled. I have not the faintest idea of the results of trying to work within a photographic studio that floated about more or less independent of the angles and motions of the major bulk surrounding it. But something tells me that the sea would call for its own.

The darkroom was a large room easily accessible from either the photographic room or from the main deck and the laboratories. Entrance was through a light lock—walls so arranged as to prevent the light from entering while doing away with the necessity of having a door. This arrangement was especially good when the vessel was in the tropics, as an electric fan placed in front of a ventilator caused a constant stream of fresh air to circulate. Suitable shelves, racks and cupboards were placed about the room and there was a large sink supplied with fresh water which circulated through the ice boxes before coming to the photographic room.

Of the many cameras, lenses and other photographic equipment there is very little need to write. Individual opinions vary to such an extent that other photographers would not agree with us as to what combinations are best.

Our equipment, however, contained four motion picture cameras,—one of these being of the super-speed type, capable of photographing up to sixteen times the normal speed. Graflex and suitable view cameras were also used. A wide-angle lens was found to be exceptionally useful on shipboard, as well as a 75 mm. Teleplat lens for making direct enlargements of small animals.

All developing, with the exception of the development of the motion picture film, was done on board. Tank development employing standard, prepared developers was used almost entirely.

On an oceanographic expedition where fresh water must be conserved, the problem of washing negatives becomes somewhat difficult. After a few weeks of experimenting, we decided to wash our plates and films in sea-water, after which a short thorough bath in fresh water removed all traces of the salt. This also introduced a difficulty as the water from the ocean often reached a temperature of eighty-two,—far too high for the safe development of plates. This was circumvented by bathing the plates in a solution of pure chrome alum just before they were put into the fixing solution.

### WORK-SHOP EQUIPMENT

The work-shop was fitted up especially for experimental work such as making new devices for capturing marine animals and the dozens of other objects that can only be conceived and made on an oceanographic expedition. For this purpose it was equipped with a large assortment of machine, carpenter's, plumber's and other tools, in addition to a forge and a lathe.

Large assortments of wire, pipe, lumber, iron and various types of bolts, nuts and screws were aboard. The work shop was also the headquarters for sister-hooks, cable clamps and the dozens of other similar objects used daily whenever the ship happened to be trawling.

The workshop likewise contained the underwater electric lights that were used to attract animals whenever the ship was stopped.

### SMALL BOATS

In addition to the life boats required by law, the *Arcturus* carried seven, small row boats. Previous experience about the Galapagos Islands during the "Williams Galapagos Expedition" had demonstrated the suitability for work along shores and in bays and harbors of small, fairly-light, round and flat-bottomed row boats capable of holding two or three people.

Two of our boats were round bottomed skiffs, 15 feet long. The five flat-bottomed boats were 14 feet long. They were standard models,—a four-lap skiff, with longitudinally planked bottom oak frames and floor timbers, and with pine seats, two pairs of oars and oarlocks. Two of these had a glass window 14 inches square, built into the bottom, so that animals beneath the surface could be easily observed, and suitable places selected for diving. These windows were placed at the bottom of a well, so that if the glass did break, the water would be unable to enter the boat. Both the round and flat bottomed boats had square sterns, to which we attached small, portable gasoline motors.

This combination of boat and motor is ideal for work in protected situations, and it has stood up very well in moderately rough water, although it is not too comfortable under such conditions. For landing on an open beach through small surf, the motor can be tipped so that the propeller is completely out of water. The boat can run in under its own momentum or else be rowed ashore without

the probability of the propeller blades hitting bottom. The weight of this combination is also a consideration. With these boats, and especially the round bottomed ones, one man can land the boat upon a beach, and by walking the boat around end for end, move it far enough in shore to be free from the possibility of destruction in the surf.

The motors used were very small, aluminum, two-horse-power machines. with self-contained dynamo, tank and cooling system. They weighed thirty-five pounds when fully equipped and would travel about twenty miles to a gallon of gasoline. The gasoline tank held five pints, sufficient to operate for twelve miles. Their usual speed was between six and eight miles an hour.

For more sea-worthy purposes two motor launches were carried, a 28 foot yacht tender with a four cylinder motor, and a 35 foot launch with a three-cylinder heavy-duty engine.

The possibility of engine trouble or other circumstances demands that these boats be adequately equipped. Ideal equipment for work about islands such as we stopped at would include oars and oarlocks, life-preserver, anchor and suitable amount of rope, extra gasoline and small funnel, wrench and screwdriver, matches in a waterproof container, and a suitable amount of food and water. Such materials take up but little room and prove their worth when called upon.

#### DIVING EQUIPMENT

Two diving helmets were included in the equipment placed on board the ship. The usual conception of a diving suit is that of an immense bulging suit, heavily-weighted shoes, and a spherical helmet from which hoses and ropes lead to the upper world. For deep water work such an outfit is indispensable, but for shallow waters ranging down to thirty feet, such as we wished to explore, the simpler outfit employed by us and manufactured by the Miller-Dunn Co. of Miami, Florida, was ideal.

The apparatus consisted of a helmet and a pump, and a hose which connected the two. The helmet is cylindrical in form, about  $22\frac{1}{2}$  inches high and 10 inches in diameter, and with the lower end open and curved to fit the shoulders. The upper end is closed in, curved upward into a dome, at the top of which is a small handle by which the helmet can be carried. In front and placed at a slight

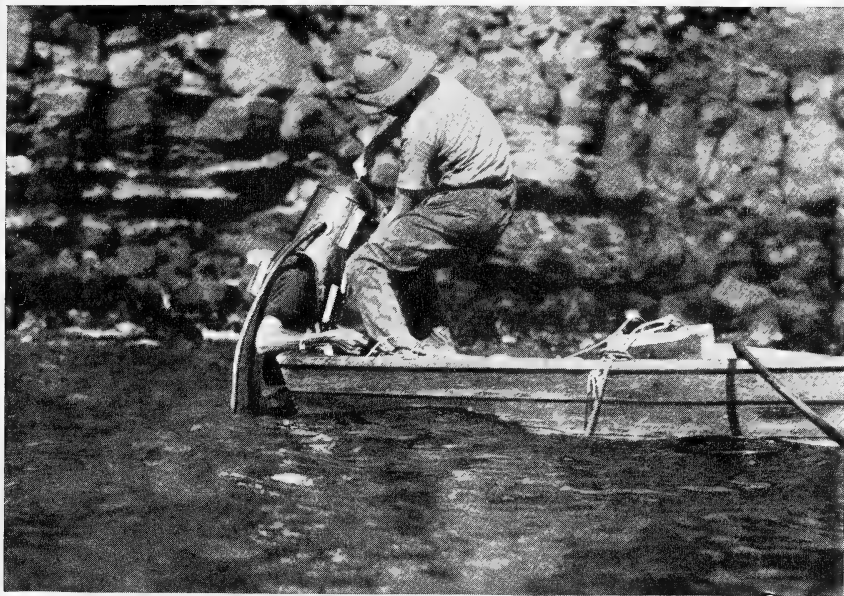


Fig. 28. Diving helmet being placed on the head of the diver.

angle are the two windows through which the diver peers. These are quite large, the height of each one being 10 inches and the width at the widest part  $4\frac{1}{2}$  inches. The glass is the best plate obtainable. In case of breakage the metal frame can be removed and new glass inserted. To avoid the possibility of breakage, however, two metal bars are placed across the windows. On the right hand side just a little above one's ear is an inlet for air. On the outside this inlet is a simple pipe, bent downward and threaded to receive the end of the hose. On the inside is a small deflector, built to prevent the air from striking directly on one's ear or face.

The hose is of the common garden variety,—one of our helmets being equipped with a sixty foot and the other with a hundred foot length. It is smooth inside and out. Wire-bound hose, although less likely to kink, would be more troublesome to handle.

The pump is a very simple, double-action, automobile pump, with a long, upwardly projecting handle. It is operated by pushing the handle back and forth, the double action forcing an almost continuous stream of air down the hose to the helmet.

Four ten-pound lead weights are also a part of the outfit, and without them descent would be impossible. They are fastened by a clip to the front and back of the helmet on the portion that projects over the back and chest.

One great advantage that this helmet has over a diving suit is that in the event of an emergency the diver can free himself by throwing the helmet aside and swimming to the surface.

During practically all of the descents made the diving was done from one of the glass-bottomed flat boats, with a crew of two men in addition to the diver. After selecting a suitable situation the anchor was cast out in such a direction that the wind and current would carry the boat over the desired spot. Then a metal jacob's ladder was fastened to the boat and the lower end thrown out over the stern. The ladder that we found ideal for this work had round, wooden rungs, an inch in diameter, at the end of which were metal disks four inches in diameter. The original purpose of the disks was to keep the rungs away from the side of a ship. We found them especially useful in shortening the ladder or lengthening it, as extra portions could be added by shackling the disks together. Each rung was connected to its fellows by chains.

The pump was placed in the bow of the boat and the pumper remained seated during the task of supplying air.

In practically every descent bathing suits were worn, and a Turkish towel, whenever necessary, was wrapped about the shoulders to relieve a little of the pressure of the sixty pound helmet on protruding collar bones. Sometimes, in places where sharp coral and rocks were present, we preferred going down dressed in khaki trousers and shirt and with heavy leather shoes. When spiny sea urchins made it necessary to wear these, Mr. Beebe wore high, hob-nailed boots. Heavy shoes served the double purpose of preventing spines from entering and of keeping one's lower extremities from rising above one's head, an ever-present possibility with some individuals.

A certain amount of immunity from the coldness of the water was obtained by anointing the body with oil, and for this purpose we used raw linseed oil. Even in warm tropical waters lengthy immersion can produce a decided impression of coldness.

When going down the diver passes over the stern of the boat and stands on the rungs of the ladder, first immersing himself to the neck.

The helmet with weights in place and connected by the hose to the pump is then placed on his shoulders,—the air supply being started immediately. A single loop of the hose was placed about his arm and the diver would slowly move down the rungs of the ladder. Going down slowly is absolutely necessary, as the difference in pressure is felt immediately. Most people, especially the inexperienced, find it desirable to keep in mind as they descend, the phrase “keep swallowing.” The man at the pump has meanwhile been pumping at the rate of a little less than one full stroke a second. The amount of air necessary varies with the individual, the depth and the length of time he has been under water. Enough pressure, however, must be maintained to keep the water from entering too high into the helmet. As is natural, the variation in depth is correlated with a difference in the amount of effort expended at the pump. The surplus air in the helmet escapes at the open space about the shoulders.

With this type of helmet it is not possible to lean backward or forward to any extent, as the air which normally reaches to just below the chin, soon reaches above the mouth.

Communication was by means of prearranged signals transmitted to the surface by jerking the air hose or by using a small rope for this purpose. The air-hose method is simpler and as effective.

It was the duty of the second man in the boat to take care of all the apparatus before the diver went over, to place the helmet on the diver's shoulders, to watch for possible kinks and signals in the air hose, and to lower spears, harpoons and pails to the man below, and to remove the helmet when the diver emerged. During the descent he watched through the glass bottomed well in the boat, or preferably through a water glass laid on the surface, for any dangers.

#### A DAY'S OPERATIONS ON BOARD THE ARCTURUS

The ultimate purpose of all the apparatus that has been described was to capture and bring to the surface the organisms found in the sea, so that they might be identified and studied and eventually brought back to civilization. Thus the frictionless running of the apparatus and of the personnel became a vital factor in the success of the expedition. If there is friction, results grow less in volume and poorer in quality. To show how our activities were correlated can best be done by describing a typical day's operations on board the ship.



Whenever possible the program for the day was worked out the night before. This schedule was typed; one copy put on a bulletin board and another given to the captain, who was thus able to communicate this intelligence to the engineering department. In this manner considerable economy was effected in the consumption of coal and water, as the fires in the boilers could be lowered hours before the time for dredging and trawling, when only a small amount of steam was necessary to keep the ship in motion.

A composite copy of one of these schedules is given below:—

Station 00		Locality
Date		
1.	5:15-5:45 A.M. Tow nets, surface.	
	Meter #2	
	Foot #20	
2.	5:45 A.M. Sounding	
3.	Temperatures and water samples	
4.	8 A.M. Trawls and tow nets.	
	Petersen trawl	1200 fathoms
	Meter net	1200 "
	" "	1000 "
	" "	900 "
	" "	800 "
	" "	700 "
	" "	500 "
	" "	250 "
	$\frac{1}{2}$ meter net	Surface
5.	1 P.M. Trawl, 10 foot Blake.	
6.	7:45-8:45. Tow Nets, Surface	
	Meter #2	
	Foot #20	

These schedules were followed whenever possible, but we had no compunction in altering plans. Our crew being a merchantman crew, we were limited in the workings of some of our apparatus, to eight hours a day. This limited also the length of time that our nets and dredges could be towed. A string of nets such as shown in the schedule takes a long time to lower and raise, and in order to bring them in before the men went off duty sometimes meant taking a half hour from the time that they could be towed. The general run of hauls, however, were with a smaller number of nets than is shown in the schedule, which gave a considerably greater towing interval.

Before beginning with the daily happenings it may be well to mention the few tasks that were constantly attended to by the officer on watch. While at sea, in addition to the regular information that is recorded, such as temperature, barometric pressure and the conditions of wind and sea, this officer took observations every two hours of the temperature of the water at the surface. At the same time he threw a drift bottle into the ocean,—an ordinary, glass, soda-water bottle, tightly corked, inside of which was a printed slip containing a number. This number coincided with the latitude and longitude of the place where the bottle went overboard.

The printed slip contained a request that the slip be returned to the Hydrographic office of the United States Navy or to the Zoological Society with the finder's name and address and information as to where it was found. Exceedingly interesting observations have been made as the result of bottles of this type. Some have travelled thousands of miles from where they started.

Before daybreak, in the tropics usually at 5.15 A.M., the ship was slowed to two knots and the first plankton nets, usually a meter or half meter net of coarser bolting cloth, and a foot net of No. 20 cloth were thrown overboard and towed.

Plankton organisms are usually near and at the surface during the night, and they start to migrate downward soon after the appearance of dawn. Thus in order that representative samples be taken it was necessary that these nets be towed before day-light in order that an adequate sample would be obtained. The length of time during which the net was left in the water varied with the locality and with conditions of weather. In the Pacific, from Panama to the Galapagos Islands, 15 to 20 minutes would not only fill the bottle at the end of the net, but the plankton would often extend in a solid mass for six or eight inches above the bottle. In contrast to this abundance were our hauls in the Sargasso Sea, where an hour's haul would result in a thin layer of animal life at the bottom of the jar and a few sprigs of sargassum weed.

During the first few weeks of the expedition the tow nets were towed from the poop, but subsequent work demonstrated that the boom-walk was a more convenient place. The length of rope needed varied with the net and with the height of the ship out of water. If the net came out of water too much, as the ship dipped, the tow line was lengthened or a 10 to 20 pound weight added until the net re-

mained just beneath the surface. Rope less than  $\frac{1}{2}$ -inch in diameter was not used, as a sufficiently strong grip can not be had with a smaller rope.

We found that a man could not pull in a meter net while the ship went ahead, although he could pull in a half-meter net. So we attached a second line to the bridle and led it back to a place abeam of where the net towed. From this situation the net could be lifted out of water and hauled aboard with the greatest ease. During the early morning hauls, however, this was not necessary, as the ship was stopped at the end of the tow in order that the sounding could be made.

Soundings were made with the ship stopped and held as stationary as possible with the bow toward the wind and sea. As the sounding line must be vertical it was often necessary, especially in heavy winds, to start the engines and maneuver the ship during the sounding until the line was straight.

The proceeding in sounding was in most cases as follows:—After the sound wire was led through the meter wheel and pulleys and the tube attached to the end, the sounding weight was attached to the tube and allowed to swing clear of the boom-walk. Then, when the officer on the bridge signalled that the ship had stopped and that he would keep her steady, the weight was allowed to run out. When the weight touched bottom, the time and depth in meters was recorded and the wire reeled up. The time for a sounding in 2803 fathoms (5126 meters) has already been given. At Station 78 in 1323 fathoms, or a little over a land mile and a half, the complete sounding was made in 20 minutes.

As the reeling-in progressed the surplus water was removed by passing the wire through two or three thicknesses of heavy burlap. A film of oil was flowed over the wire on the drum. Automatic oiling devices were made, but they were not especially successful. Eventually the oiling was done with a small brush dipped in oil which was applied to the wire after each layer was wound.

When the "stray line" reached the surface the reeling in was slowed down until the sounding tube was in the hands of the operator. The tube was then unfastened and taken to the laboratory where the bottom sample was removed. This was done by pressing the plunger at the bottom which opened the valve and let the sample pour out. Especial care was taken to see that all the sample was

removed. Sticky oozes and especially some of the clays often become firmly attached to the inside of the tube and especially to the valve seats. The tube was afterward cleaned and stored for the next descent.

The surplus water in the bottom samples was removed and the samples stored in bottles. As most of our samples, after determinations had been made as to bottom-types, were to be examined for the presence of nematodes, they were treated with corrosive sublimate before they were preserved.

The usual sounding crew consisted of three men,—the operator of the machine, a man who recorded the depth and time, and the man on the boom-walk who attached the weight, removed the surplus water from the line as it came up, and disengaged the tube with its attendant sample.

With the depth known, such operations as taking temperatures, and trawling and dredging could begin. Whenever possible temperatures were taken early in the morning before the nets were submerged. If the sounding had shown it to be necessary the depths at which the nets were to be sent was modified.

For temperatures four persons were required,—a winchman, one to record the temperatures and label the samples, and two men on the platform, who attached the machines, read the thermometers and bottled the water samples. During high winds an extra man was delegated to pull the cable close in to the ship by means of a block and tackle that was attached to the wire whenever a thermometer-water-bottle had to be attached. This was necessary at times because the ship, when the thermometers were in use, could not always be held head to the wind and sea. If the ship was held to the weather there was always a likelihood that she would slew around and over the cable, and if this happened there was a possibility of scraping a thermometer off the cable as it came alongside the hull. To obviate this we tried to have the wind on the port bow or abeam. Thus the ship made leeway and as the wire described a slight curve away from the side we found it necessary to have the extra man. The procedure and operation of the thermometers has been given in the section on Thermometers.

When working at night we found that a small electric flashlight with dimly-shining bulb was most efficient for reading the thermometers.

Breakfast was at seven in the morning. Before 8, whenever possible, the meter nets were examined for holes in the fabric or other deficiencies and the plankton bottles were tied into the ends.

At 8:00 the winchmen and sailors came on duty and prepared the machinery for trawling. A Petersen trawl was attached to the end of the cable. The bridle was then hauled up until the boards were up as close to the pulley at the end of the boom as they could go. The ship meanwhile, was under slow headway, moving at a maximum speed of 2 knots, and with only the port propeller in action. The trawl was put over-side and trailed in the water. It was allowed to pay out until the end of the cable passed the deck, when it was stopped and the 150 pound weight attached to the end of the cable. Then, if the otter boards were pulling in the right way, more cable was let out and the net, boards and weight slowly left the surface. After 20 meters of wire was out the drum was stopped and the cable drawn in toward the side of the ship, in order that a meter net could be attached. All of these distances between nets were measured by the meter-wheels, and one of the staff was always detailed to see that the correct measurements were made.

The cable was often a considerable distance from the ship and to bring it alongside, we either threw the stern of the ship over, so that the wire came alongside of the hull, or else, under certain conditions, pulled the cable in by means of a hook and rope attached to a donkey engine. The wire when nets were being towed usually came alongside the ship just aft of the foremast stays.

During the first part of the expedition, as I have mentioned, we fastened the nets to the cable by means of cable clamps, and later we used the brass balls. Subsequently, we found that the hinges on these spheres had been constructed too weakly, and in order to make certain that they did not slip down the wire because of this, we placed a cable clamp beneath them. The net was then fastened to the cable by means of sister-hooks. When this was done the wire travelled out again, slowly until it was evident that the net would be clear, and then more rapidly. The process was repeated until all the nets were on the line and they were then towed the desired length of time.

At Station 113, 100 miles outside of New York, six meter nets were sent down at 100 fathom intervals from 500 to 1000 fathoms, and a Petersen trawl just below the lowermost net. The entire

operation of fastening the nets and sending the cable down occupied 1 hour and 9 minutes. Attaching the nets took 15 minutes and the remaining 54 minutes were occupied in letting the cable out. Bringing them in was a somewhat lengthier process, the whole proceeding taking one hour and fifty-five minutes.

In the afternoon of the same day a similar series of nets were sent down, also at 100 fathom intervals, from 700 to 1200 fathoms. These were sent to their respective depths in 59 minutes,  $16\frac{1}{2}$  minutes of which were with the cable stopped while the nets were being attached. As with the preceding group, coming to the surface was slower, taking 2 hours, 20 minutes of which were used in removing the nets.

These two hauls were made at slightly greater speed than usual. The rapidity of such operations depends greatly upon the training of the crew and the facility with which the nets can be handled.

In all cases, when nets or Petersen trawls were towed, the amount of cable out was always 50 per cent. greater than the actual depth. Thus to send a net to 100 fathoms required 150 fathoms of line, to take care of the fact that the line went down at a 45 degree angle. When towing on the bottom the length of line was often considerably greater than this.

The length of time that such nets were hauled varied in the same way as was mentioned for the surface nets. In densely inhabited waters such as we found in the Pacific a half hour or less would result in a full bottle. At Station 113 the hauls were all short, one being 30 minutes and the other forty-four minutes. While coming up all of these nets strained through a zone of *Salpa*, and each one came to the surface with two to three pailfuls of those interesting, crystal-like animals.

One or two experimental hauls ought to be made in each region to determine the most suitable length of time for towing. In certain regions of the oceans, hours of horizontal towing are necessary to obtain a representative view of the fauna.

Bringing the nets in was similar to that of sending them out, with the exception that we took turns in beating the cable, while two men were detailed to see that the cable rolled up on the drum in the right way. This was usually done so that the last net arrived on board by 12:00 o'clock, when the crew went to lunch. As the nets were brought alongside the ship they were removed

from the line, the bottles taken out, their contents emptied into a pan, and the organisms immediately sent to the laboratory for study. The members of the staff also had lunch at 12:00 after which the afternoon's nets were prepared for action. At 1:00 o'clock the men again came on duty and lowered the dredges or trawls or whatever happened to be on the program.

When otter trawls were used the procedure of putting them over was similar to when the Petersen trawls went out. But owing to the greater length of the bridle, we found it necessary to carry the net back to the poop and put it into the water from there. As the net went into the water and the boards opened out, the stern was swung slightly to port until nets and boards were completely free from any possibility of fouling. The otter trawls were used occasionally for intermediate towing, but they were practically always sent to the bottom. At Station 74 we lowered a trawl to 650 fathoms for one of the best hauls made during the expedition. For this purpose we used a 40-foot trawl with 150-foot bridles, 50-pound otter-boards, a 150-pound ball at the end of the cable and a 50-pound ball at the end of the net. This net took 49 minutes to reach the bottom and 50 minutes to come up, after having towed on the bottom for 1 hour and a half.

When we sent down the Blake trawls the weight at the end of the cable was omitted. They were slowly lowered, while the ship crept ahead. When on the bottom after a sufficient amount of cable was allowed out, they were towed for whatever length of time was deemed sufficient. A Blake trawl lowered in 844 fathoms arrived at the bottom in 28 minutes, was slowly towed for 2 hours and came to the surface in 38 minutes. The time for descent and ascent, especially the latter, varies considerably, depending upon the conditions of sea and what the dredge has encountered on the bottom.

If the dredge arrived at the surface with a large amount of mud in the bag, it was emptied on deck. The mud was then placed in sieves and, by playing a stream of water over it, the animals were soon revealed.

The operation of dredges and trawls and tangles that dredge on the bottom differed from the working of the other nets in that the towing apparatus was connected with the cable. But as this machine was automatic it made no difference in the number of men needed. The chief officer, however, usually watched the dynam-

ometer at the base of the towing engine, and the amount of tension was recorded every time there was an appreciable change.

The men necessary for a dredging or meter net operation consisted of a winchman, two men to lead the cable on the drum and to oil it, two men to attach the nets, the chief officer who controlled the operations, and a member of the staff who watched the meter wheel, calculated the depths and generally supervised the work.

When the vertical nets were used, the ship was stationary. The cable was rigged through the sheave on the davit over the platform on the port side, or through a pulley on the dredging boom, as shown in the illustration on page 77. This allowed the nets to come alongside in a place where they could be easily handled.

These nets, rigged in the same way as the vertical closing net, except that the closing arrangement was omitted, were put over the side, sent to a certain depth and then slowly hauled to the surface. They were sent down a number of times, the depth at each immersion being increased. Thus we made a series of hauls, say from 500 meters to the top, then from 600 up, and then from 700, 800 and 900, and so on. This gave us a fair idea of what animals were in the different zones.

The use of vertical closing nets was a more definite method of accomplishing the same object. These nets, rigged as on pages 77 and 79 were sent to the various depths, raised a certain distance, closed by means of a messenger sent from above, and then brought to the surface. Thus the animals living in the zone between 800 and 1000 meters were caught by sending the net down to 1000 meters, hauled to 800 meters, closed and brought up.

Where the fauna was scanty the closing net was towed within the zone that was to be investigated. Let us use the 800-1000 meter zone again as an illustration: The net was sent to 1000 meters. Then the ship started forward slowly, great care being taken to watch the angle of the cable. If the angle became too great and the calculations showed that it was approaching the 800-meter line the ship was slowed down until the angle lessened. Then the net pulled in to the 800-meter line closed with its haul and raised to the surface.

The contents of the vertical nets were carefully saved as their importance lies in saving every organism taken in the net, so that



they might be counted and an estimate made of the richness of life in whatever zone was examined.

At 5:00 P.M. the trawling crew went off duty, and between 5:30 and 6:00 the staff had dinner.

At night a series of surface tow nets were thrown over, often at half-hour intervals. Twice during the expedition, surface nets were thrown over for 30 minutes of each hour for 24 consecutive hours. This gave an interesting cross-section of when and in what order the plankton animals rose to the surface.

Complete records of all proceedings and captures were taken. Thus the contents of each net and the conditions surrounding each capture were carefully recorded, in addition to the physical details of each station and the many other observations that were made more or less automatically.

The details of a typical day's activities must of necessity be considerably varied, and this account represents but a fragmentary portion of the ship's operations. The contact with land has been omitted entirely. Yet it is hoped that, meager as it is, this account will give a faint view of what our equipment was like and what we did with it.

# ZOOLOGICA

## SCIENTIFIC CONTRIBUTIONS OF THE NEW YORK ZOOLOGICAL SOCIETY

DEPARTMENT OF TROPICAL RESEARCH  
ARCTURUS OCEANOGRAPHIC EXPEDITION

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### BROTULID FISHES

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## BROTULID FISHES\*

### FROM THE ARCTURUS OCEANOGRAPHIC EXPEDITION

BY ELIZABETH S. TROTTER

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(Figs. 29-33 incl. and Plate C.)

#### INTRODUCTION

Of the family Brotulidae, 80 specimens, representing 6 genera and 7 species, were taken by trawl, otter trawl and dredge in the following order:

AT STATION 26 Lat. 5° 03' N. Long. 81° 08' W.

*Cherublemma telepris* gen. nov. 1 specimen

At STATION 74 Lat. 4° 50' N. Long. 87° W.

*Lamprogrammus illustris* 2 specimens

*Mixonus caudalis* 1 "

*Porogadus breviceps* 5 "

*Dicrolene nigra* 33 "

*Dicrolene gregoryi*, sp. nov. 1 "

*Monomitopus torvus* 35 "

AT STATION 84 Lat. 0° 17' S. Long. 91° 34' W.

*Monomitopus torvus* 3 specimens (young)

AT STATION 86 Lat. 0° 42' S. Long. 91° 47' W.

Undetermined Brotulid 1 specimen (very young)

At STATION 87 Lat. 0° 00' Long. 91° 53' W.

*Monomitopus torvus* 1 specimen (young)

All of the brotulids of the Arcturus Expedition were taken from four stations in the Pacific Ocean between Panama and the Galapagos Archipelago. The majority, including all of the adult specimens, were taken at Station 74, the biggest station, in every sense of the word, made by the *Arcturus* during her whole six months voyage.

\* Contribution, New York Zoological Society Department of Tropical Research, No.

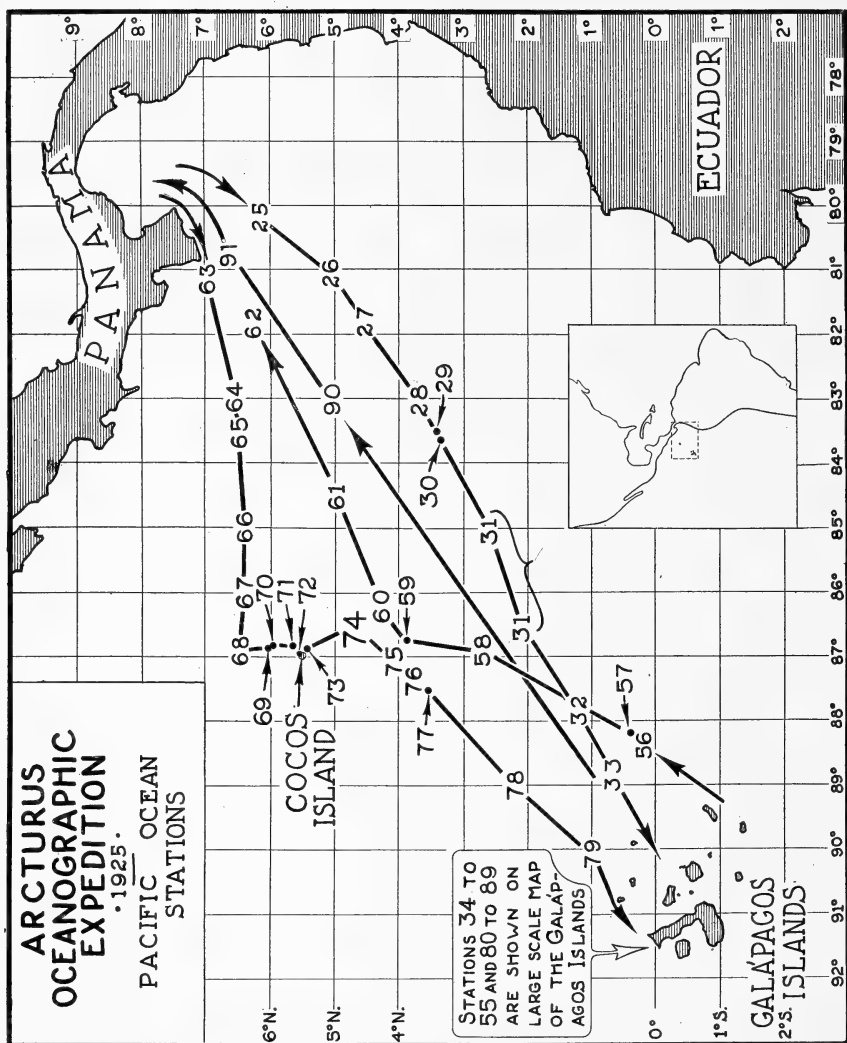


Plate C. Galapagos Islands' Stations. Arcturus Oceanographic Expedition.  
From a drawing by John Tee-Van.

Station 74 endured for ten days while the *Arcturus* drifted within the immediate vicinity of Lat. 4° 50' N. and Long. 87° W. It was a station most lavish in material, especially fishes and crustaceans, which triumphantly corroborated Mr. Beebe's belief that the ocean may be investigated by the acre as well as by the degrees of the meridian. And it may be added that Station 74 was our dampest above water, for it was but sixty miles south of Cocos and consequently still within reach of the clouds gathered by that luxuriant and moist island.

Until Station 74 we had taken but few fishes from the deep sea that were not, in their diminutive frailness, incongruous when compared to the size and coarseness of the nets that had caught them, and we had grown used to preparing for the return of the immersed trawls with an array of glass jars and bowls and small aquaria. Very shortly, however, after Station 74 was made on May 25, 1925, we began to receive intimations that tubs and buckets and large aquaria had best be got ready.

On May 27th, the first brotulid, *Lamproprogrammus illustris*, came up in T<sub>19</sub> from a depth of 450 fathoms, and it was still, though feebly, living.<sup>1</sup>

On May 28, the first macrurid was taken in OT<sub>1</sub> from a depth of 900 fathoms.

On May 29, the otter-trawl, OT<sub>2</sub> from a depth of 750 fathoms brought up a load of small fishes, a few bathybial forms but mostly the delicate *Cyclothone*, *Argyropelecus*, and species plentiful in the shallower depths. While on the same day another otter-trawl, OT<sub>3</sub>, from 833 fathoms, contained practically none but abyssal forms, including three brotulids and six macrurids.

On May 30, the otter-trawl, OT<sub>4</sub> brought up the largest deep sea haul of the trip for, without considering the meagre scattering of Silver Zone fishes that were caught in the mouth of the net on its way up, or the numbers of other abyssal forms, OT<sub>4</sub> from a depth of 625 fathoms contained 71 brotulids and three macrurids. Another net on the same day, OT<sub>5</sub> from an equal depth contained but one brotulid and only seven or eight other fishes, so enormously dependent on "luck" is fishing at such very long range.

On May 31, a dredge, D<sub>1</sub> from 844 fathoms added to our collection of big fish—some of them well over a foot in length—by one more brotulid and two more macrurids.

<sup>1</sup> Cf. "The *Arcturus* Adventure," by William Beebe, p. 362; fig. 54.

And on June 3, the last brotulid from Station 74 came up in another dredge, D<sub>3</sub> from 765 fathoms.

I have chosen to mention the numbers of macrurids that were caught along with the brotulids because these two families are so significantly alike in their general appearance and also in what is known of their habits and distribution. Their representatives taken by the '*Arcturus*' certainly exhibit a conspicuous similarity of modification, enough to indicate that they enjoy at least the same kind of life. It seems reasonable to mention briefly some of these similarities because it is still a disputed question whether the brotulids are, phylogenetically, close to the macrurids or not.

These two families are similar in having soft, flabby bodies that dwindle to the most minute of caudals, although there is nothing in the least eel-like about their general expression.

Their heads are pitted with muciparous channels, although these are more conspicuous on the brotulids.

Their ventrals have undergone much reduction and must be used as tactile organs, if indeed they have not dwindled beyond any usefulness; and it is these ventrals, and in some genera filamentous pectorals, that are an indication of the bottom dwelling habits of these fishes. Their teeth are villiform, so fine (in most cases) that the French word for the character of their teeth, *en velours*, is most descriptive.

It is believed that these two families of fish are carnivorous, but not predatory, animals. To a superficial eye, however, it seems as though their ways of getting their food must be different, for in the case of the macrurids, the rosettes of spines on the tips of the elongated rostrums seem admirable instruments for stirring up the bottom mud together with the small creatures in it. The brotulids on the contrary have blunt snouts and their mouths are larger and better suited to engulf a bathybial, free swimming shrimp than to grub along the bottom.

With the exception of the specialized genus *Lamprogrammus*, all of the *Arcturus* macrurids and brotulids have the eyes peculiarly modified. Their eyes are covered with a heavy, rather opaque membrane that is continuous with the dark skin of the head, a very tough membrane with the eye set well behind it, its iris appearing like a soft blue ring.

Whenever macrurids and brotulids arrived upon the deck of the *Arcturus* they displayed the same symptoms of distress; most of

them had their heads thrown back, their branchiostegals spread like straining wings, and their mouths gaping; while a few individuals seemed quite untroubled by the swift change of pressure—except that they were dead.

These characters do not necessarily imply that there is a phylogenetic relationship between the families, for they are readily explained by the equalizing effect of an extremely uniform and exacting environment upon fishes that originally may have been highly dissimilar. But in view of these structural similarities it may be found that the habits of the little known Brotulidae are to the same extent similar to those of the better known Macruridae.

The macrurids are the best known of all the deep sea fishes, for although the brotulids have also been found in all the oceans, the latter have not even been given a secure classificatory niche, since it is still an open question whether they belong to the Acanthopterygii or the Anacanthini. Günther in 1873<sup>2</sup> included the brotulids in the Ophidiidae, while Brauer<sup>3</sup> placed them in the Zoarcidae. Then Goode and Bean<sup>4</sup> in 1895 raised them to family rank:—Brotulidae, under the super-family, Ophidoidea. And it was regarded as an accepted fact that the Brotulidae, closely associated with the Ophidiidae and the Zoarcidae, should come under the suborder Jugulares of the Acanthopterygii, and that they were to be looked upon as “degraded blennies,”<sup>5 6</sup> their resemblance to the Macruridae being entirely superficial. In 1899, however, Garman,<sup>7</sup> apropos of the lateral line systems of deep sea fishes, said: “The peculiar disks in the canals, hardly to be detected in those (species) of the shoals, attain a much greater development in the bathybial species and, in position and arrangement clearly indicating genetic relationship through common ancestry, are similar in families that in our systematic arrangements are widely separated.”

On the basis of his study and comparison of the lateral line systems, Garman removed the families Zoarcidae, Ophidiidae and Brotulidae from the Acanthopterygii and placed them with the Gadidae and Macruridae under the Order Anacanthini.

<sup>2</sup> “Deep Sea Fishes,” by A. Günther. Report of the Scientific Results of the Exploring Voyage of H. M. S. Challenger, 1873–76. Vol. XXII.

<sup>3</sup> “Die Tiefseefische,” by A. Brauer. In Chun, Wiss. Ergebnisse Deutsch. Tiefsee-Exped. “Valdivia,” 1898–99.

<sup>4</sup> “Oceanic Ichthyology,” by Goode and Bean. Smithsonian Institute, U. S. Nat. Mus. “Fishes,” by David Starr Jordan, p. 733.

<sup>5</sup> “Fishes,” (Systematic Account of Teleostei), by G. A. Boulenger. In Camb. Nat. Hist., 1904, vol. VII.

<sup>6</sup> “Fishes of the “Albatross” Expedition, by S. Garman. Mem. Mus. Comp. Zool., vol. 24.



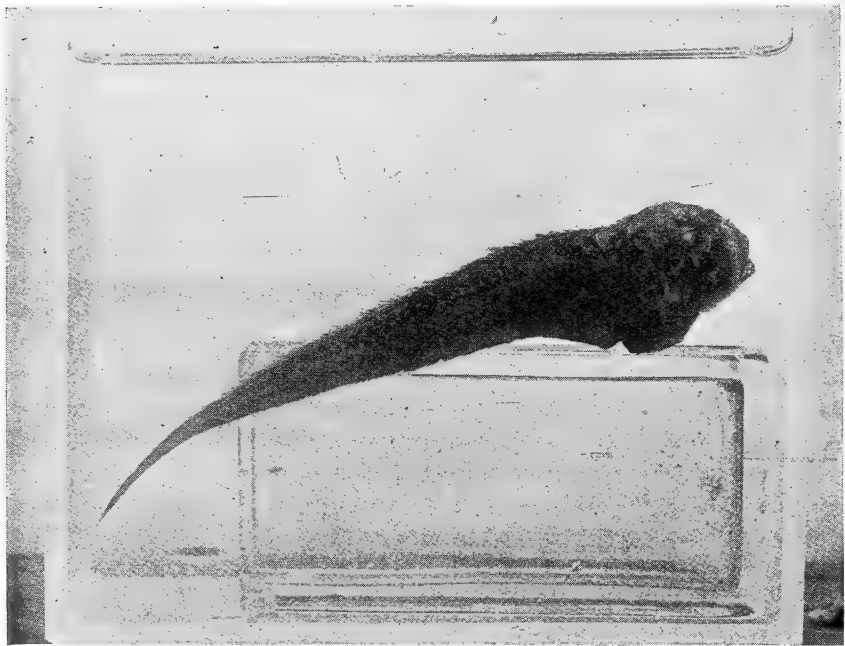


Fig. 29. *Lamprogrammus illustris* Garman. This specimen (A.M.N.H. 8451) came, still living in a net from the depth of 450 fathoms.

This arrangement of the families is further indicated to be the correct one by Cockerell<sup>8</sup> who finds that the scales of the Brotulidae resemble these of the Ophidiidae and certain genera of the Gadidae.

The brotulids described and studied by Garman from the *Albatross* collection in 1899 were taken from much the same region of the Pacific as these brotulids taken by the *Arcturus* Expedition in 1925; and so this discussion is largely based upon Garman's descriptions.

For all of the color notes made upon fresh specimens, Ridgeway's color key book was used.

*Lamprogrammus illustris* Garman.

Mem. of the Mus. of Comp. Zoology XXIV, 1899, p. 174, Pl. XXXIV.

Station 74, in T<sub>1</sub>, from 450 fathoms one specimen (Field no. 5948) A.M.N.H. 8451; and in OT<sub>4</sub> from 625 fathoms one specimen (Field no. 6037) A.M.N.H. 8452.

<sup>8</sup> "The Scales of the Brotulid Fishes," by T. D. A. Cockerell. *Annals and Magazine of Natural History*, Oct. 1916, 8th ser., vol. xviii.

Of these the first, no. 5948 (8451) is probably not fully grown. It measures in length from snout to base of caudal, 126 mm.; in width across pectoral fin bases, 8.5; depth, between nape and humeral symphysis, 18.5; eye diameter, 3.2. It agrees well with Garman's description save in the matter of color. Garman gives no color notes, implying only that the fish is black. Our specimen, however, is a rich seal brown on head, belly and inside its mouth and branchial chambers; the same dark brown color continuing along its lateral line, while its muscular tracts are of a lighter brown.

The second specimen, no. 6037 (8452), is an adult female with partly developed eggs. It measures in length from snout to base of caudal, 260 mm.; width across the pectoral fin bases, 19 mm.; depth between nape and humeral symphysis, 44 mm.; eye diameter, 5 mm. It agrees well with Garman's description, differing only in that its head is slightly longer than deep and its eye slightly smaller than  $\frac{1}{2}$  the snout. It differs in body proportions from the smaller specimen no. 5948 (8451) but not greatly enough to indicate any specific difference. In color, however, this specimen 6037 (8452) is a deep blue on head, body cavity and inside its mouth and branchial chambers, the same blue continuing along its lateral line, while its muscular tracts are lighter and show a distinct purplish tinge.

Of all the Brotulidae the members of the genus *Lamprogrammus* are among the most interesting as examples of brotulid specialization. Their eyes are in the act of becoming lost behind very large mucous canals; their ventrals are quite gone, and they have developed a most intricate and conspicuous lateral line system, beautifully described by Garman, and well shown by these two specimens.

*Mixonus caudalis* Garman.

Mem. of the Mus. of Comp. Zoology XXIV, 1899, p. 148, Pl. XXXVI, fig. 2.

Station 74 in OT<sub>3</sub> from 833 fathoms one specimen (Field no. 5978) A.M.N.H. 7504.



Fig. 30. *Mixonus caudalis* Garman. Station 74 in OT<sub>3</sub> from 833 fathoms, one specimen (A.M.N.H. 7504).

This specimen measures in length from snout to base of caudal, 394 mm.; width across pectoral fin bases, 30 mm.; depth between pectoral fin bases, 49 mm.; length of the surface membrane of its eye, 11 mm. Its total body weight when fresh was 191 g.

It agrees with Garman's description save in the following particulars: it has 105 dorsal rays as opposed to Garman: D 97-103. It has four rudimentary gill-

rakers and one long one on the upper part of the first branchiostegal arch as opposed to Garman: three rudimentary gill-rakers and two long ones. Its caudal fin is only  $\frac{1}{2}$  in head as opposed to Garman: caudal  $\frac{3}{4}$  in head.

These differences may be accounted for by the fact that this specimen is four inches longer than the one upon which Garman bases his type description.

Color notes made immediately upon this specimen's being taken from the net add to Garman's very brief color description. They are as follows: body pale shading into light rosallene purple behind the vent. Belly blackish, shading into light neropaline blue under the pectorals. Operculum dusky blue. Head pale (skin torn, however, and muciparous ridges and cavities prominently exposed). Branchiostegals blackish, linings of mouth and branchial cavities forget-me-not blue. Posterior part of the dorsal and anal fins tipped with neropaline blue. Caudal pale.

*Porogadus breviceps* Garman.

Mem. of the Mus. of Comp. Zoology XXIV, 1899, p. 155.

Station 74, in OT<sub>4</sub> from 625 fathoms, five specimens, of which only one was an adult with well developed eggs partly extruded from an opening behind the vent. This adult specimen, Field no. 6022 (A.M.N.H. 7505) measures in length from snout to the base of caudal, 340 mm., in width across the pectoral fin bases, 33.5 mm., and in the length of the surface membrane of its eye, 9 mm.; total body weight when fresh was 83.3 g.

The four immature specimens, A.M.N.H. 8456, agree with the adult in proportions as well as characters and differ only in that they are smaller, paler and more blue in color and with less distinct scales. They are all very nearly the same size, the largest measuring, in length from snout to base of caudal, 207 mm.

To Garman's brief color description we may add that they all possess what seems to be a fairly consistent brotulid characteristic, one that exists at all events among all of the adult specimens that were taken on the *Arcturus* except *Lamprogrammus*: inside of the mouth and branchial cavities forget-me-not blue; belly, branchiostegals and opercula dark indulin blue. In general body color these *Porogadus breviceps* are a light tan in color with a faint bluish tinge.

*Dicrolene nigra* Garman.

Mem. of the Mus. of Comp. Zoology XXIV, 1899, p. 150, Pl. XXXVIII, fig. 2.

At Station 74 in the dredge, D<sub>3</sub>, from 844 fathoms, one specimen (Field no. 6122) A.M.N.H. 7506; in OT<sub>3</sub> from 833 fathoms, one specimen (Field no. 5977) A.M.N.H. 7507; and in OT<sub>4</sub> from 625 fathoms 31 specimens, A.M.N.H. 8458, 8459, 8460.

All of these 33 individuals, ranging in length from 481 mm. to 125 mm. agree well with Garman's description except in the matter of color. Garman's color-notes on *Dicrolene nigra* are as follows: "Coloration of large individuals black. (His described type is but 255 mm. in length.) On the younger ones the bases of the fins appear whitish and the muscular tracts brown." This fits none of our specimens with exactitude and takes no cognisance of the marked

color variation that occurs within the species, a variation not to be confused with the color differences between the young and adult fish.

Of the 33 *Arcturus* specimens only 6 are adult; and each of these merit an individual word so striking is the color difference among them. (Field no. 6122) A.M.N.H. 7506 is a specimen measuring in length from snout to base of caudal, 404 mm., in width across pectoral fin bases, 35 mm., in depth, 57 mm., and in the length of the surface membrane of its eye, 14 mm. Color: body and head a deep, dusky blue with a few scattered scales of a lighter blue. Paired fins black. Unpaired fins also black but streaked with forget-me-not blue. Branchiostegals and belly dark indulin blue. Inside of mouth light forget-me-not blue except the top of the vomer which is Chinese violet.

This specimen has no eggs. Stomach contained a large red shrimp. *Benthescynus*, a form inhabiting the abyssal depths but not the bottom.

(Field no. 5977) A.M.N.H. 7507 measures in length from snout to base of caudal, 414 mm. Its total weight when fresh was 301 g. Color: body and head reddish brown. Paired and unpaired fins black. Branchiostegals and belly dark indulin blue. Inside of mouth light forget-me-not blue except the top of the vomer which is Chinese violet. This specimen has no eggs. A peculiar growth, possibly parasitic, on its flank behind gill-opening.

(Field no. 6044) A.M.N.H. 7508 measures in length, 463 mm. Color: definitely brownish as in 5977 A.M.N.H. 7507. This specimen has the 7 filamentous rays in its pectorals that Garman mentions as being a rare feature of the species.

(Field no. 6018) A.M.N.H. 7509 measures in length, 457 mm. Color: definitely bluish, as in 6122. Has well developed eggs.

(Field no. 6019) A.M.N.H. 7510 measures in length, 495 mm. Its total weight when fresh was 1 lb. Color: definitely bluish as in 6122. Has well developed eggs. The ovaries are enclosed in a thick membranous sack that is continuous with a funnel connecting with an opening just behind the vent. They measure 50 mm. in length, 20 mm. in depth, and 30 mm. in breadth. Dorsally they appear as one organ but ventrally their surrounding membrane has folded in, partly dividing them into right and left. Approximately there are 1500 "stems" in each ovary and upon each of these "stems" approximately 100 eggs are clustered, making a total number of approximately three hundred thousand eggs to the fish. This specimen has the 7 filamentous rays in its pectorals, sharing this exceptional character with (Field No. 6044) A.M.N.H. 7508, a specimen brownish in general color and without eggs.

Unnumbered specimen, new skeletonized, that measured in length, 404 mm. Color: definitely bluish. Had well developed eggs.

It may be seen then that of these 6 adults all of the gravid females are bluish in color and of those without eggs 2 are brownish and one is bluish. And this difference in colors persists strongly now even though the specimens have been in preservative for more than a year.

Of the immature *Dicrolene nigra* there are 27 specimens, ranging from 279 mm. to 125 mm. in length; of these 7 specimens are peculiarly distinguished by being of a darker brown, their fins black, the bases of the fins, branchiostegals and belly dark indulin blue; and the linings of their mouths the characteristic lighter blue; while 16 young specimens are distinctly, though by varying degrees, lighter in general brown tone of their bodies. The remaining specimens which

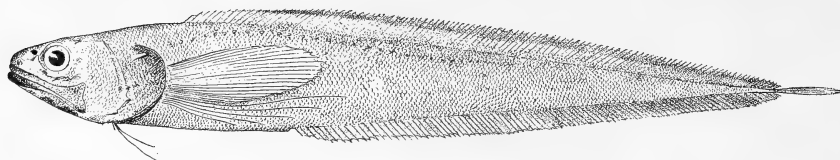


Fig. 31. *Dicrolene gregoryi* sp. nov. One specimen Station 74 in D<sub>1</sub> from 844 fathoms (A.M.N.H. 7511). From a pen drawing by Mrs. Louise Nash.

range from 153 mm. to 125 mm. in length are light enough to agree with Garman's description of the young color of the species, and the bases of their fins are definitely whitish. The color of these 4 small individuals is without question due to their youth.

As an example of the method of growth in this species it may perhaps be interesting to note that in a specimen 153 mm. in length, the body depth is 8 in its own length; while in a specimen 190 mm. in length, the depth of body is 6.3 in its own length. Thus the young fish attains its girth less speedily than its length.

It may also be interesting to note that *Dicrolene intronigra*, the principal species of the Atlantic *Dicrolene* as *nigra* seems to be of the Pacific, comes to maturity at a much smaller size, for a specimen in the American Museum of Natural History (A.M.N.H. 3159) with well developed eggs, measures but 217 mm. in length.

#### ***Dicrolene gregoryi* sp. nov.**

Type. At Station 74, in D<sub>1</sub> from 844 fathoms one specimen. (Field no. 6063) A.M.N.H. 7511.

Length from snout to base of caudal, 237 mm.; depth in length, 7.4; longest ray of upper portion of pectoral, 5 mm.; longest ray of lower filamentous portion of pectoral, 4.5; body cavity, 2.7; head, 5. Snout in head, 4; eye 4.7; mouth, from anterior edge of premaxillary to posterior edge of maxillary, 1.5; longest dorsal ray, 3; anal ray 5.5; longest (the inner) ventral ray, 2.5; caudal, 2.5 Branchiostegals 8, Dorsal 111-114, Anal 96-99, Ventral 2 (plus a tiny serrate stump), Pectoral 20 + 5, Caudal 6 or 7.

Body compressed, elongate, tapering gradually to a narrow caudal; base of caudal 2 mm. across. Snout rather blunt, slightly longer than eye, not projecting at all beyond the point of the lower jaw which is shaped to fit into the toothless gap where the premaxillaries meet at the tip of the snout. Mouth large. The maxillary extending behind the orbit to a distance equal to  $\frac{1}{2}$  of the orbit; and broadening so that its posterior edge is equal to the orbit; this broad flange of the maxillary is scaled. Teeth small, in villiform bands on the jaws and palatines, a small triangular patch on the anterior tip of the vomer and a narrow band down the middle of the "tongue" flanked a little posteriorly by two smaller bands. Eye fairly large, equal to interorbital space. Gills 4, a slit behind the fourth; rakers stout, the longest 1.6 in the eye; 4 on the upper and 12 on the lower branch of the first arch. Membranes not united, free from the isthmus. Operculum with a stout horizontal spine at its upper flap and a short spine projecting downward along its anterior surface. Three preopercular

spines and a sharp spine above the hinder border of each eye. Dorsal rays longer than anal; and the bases of these fins extend all the way to the origin of the caudal. The caudal consists of 6 or 7 rather long slender rays. The ventrals have their origin just behind the humeral symphysis; they each consist of two delicate rays that are bound together for a short distance at the base, and on the outer side of each of these and close to their base is a small serrate stump no longer than the extent to which the bifid ventral rays are bound together. The upper pectoral rays are united, the lower rays separate, long and stronger than the rays of the upper pectoral.

The lateral line is fairly prominent anteriorly, rising rather abruptly towards the dorsal fin until under about the 13th ray where it is but 4 mm. distant from the base of the dorsal; it continues along the base of the dorsal until about the 72nd ray when it disappears. Air bladder large, thick walled and white as is characteristic of many genera of Brotulidae, if not of all.

Color in alcohol; muscular tracts pale tan; dorsal fin pale along its base which is heavily and finely scaled, but tipped with dusky brown. Anal unscaled, dusky brown all over. Caudal and pectoral dark brown. Belly bluish. Opercula, branchiostegals, head and inside of mouth dark seal brown.

This species is closer to *Dicrolene nigra* than to any other of the known species of *Dicrolene*. It is to be distinguished from *Dicrolene nigra* principally by the color, the size of the eye, and most significantly by the size and number of the scales.

On an oblique line from the origin of the anal fin to the origin of the dorsal—and a single line may be followed directly between these two points—there are 65 rows of scales whereas a similar count of scales on *Dicrolene nigra* shows 80 rows. Similarly from the nape to the origin of the dorsal there are 18 rows of scales, while in *Dicrolene nigra* there are 22 rows.

This type specimen had in its stomach a small white shrimp, *Euphausia*, a form living, as a rule, above 500 fathoms.

Species named for Doctor William K. Gregory, Associate in Vertebrates on the Arcturus Oceanographic Expedition.

*Monomitopus torvus* Garman.

Mem. of the Mus. of Comp. Zoology XXIV, p. 157, Pl. XL, fig. 1.

At Station 74 in OT<sub>4</sub> from 625 fathoms, 35 specimens (A.M.N.H. 8642), of which 4, 7503, 8461, were so much bluer in color that at first sight they were thought to be of a different species and were given the temporary name of "Blue Brotulid" to distinguish them from the other larger specimens which were called the "Brown Brotulids." Upon examination it was readily seen, however, that these "Blue Brotulids" were of the same species.

They all agree well with Garman's description, with the possible difference that many of them have but 29 and 30 rays in their pectoral fins instead of: pectoral 32-33; and except for a decided color variation within the species. For beside the difference in color displayed by the four small "Blue Brotulids," that average 140 mm. in length, there is a distinct variation among the adult fishes.

The color of the species as a whole is as follows: body brown, fins a darker

brown; forget-me-not blue scales scattered over the unshaded brown of the muscular tracts and concentrated at the bases of the unpaired fins and of the pectorals making the color in those spots pronouncedly blue. The color of the four young fish, the largest of which measures in length 145 mm., differs from this description only in that the muscular tracts are of a paler tan overlaid with a powdery blue tinge.

But among the adult fishes that range in length from 406 mm. to 210 mm. there is a color difference not to be explained by immaturity. For of 31 adult individuals, 15 are of a much darker brown and have more conspicuous blue scales overlying the brown. All of these 15 individuals have eggs in various stages of development, while of the 16 specimens that do not have eggs, 4 are dark and covered with scales of a deeper blue, indistinguishable in color from the gravid females; and 12 specimens, though by varying degrees, are light and the bases of their fins are tinged with a paler blue.

Some of the individuals without eggs are smaller than any of the gravid females, it is true, for the smallest specimen carrying eggs is 220 mm. in length, and there are four specimens without eggs that are smaller than this. But of these four specimens 2 share the dark color of the mature females while the other two are conspicuously lighter.

As an example of the method of growth in this species it may be noted that in a specimen 310 mm. in length, the body depth is 5.6 in its own length; while in a specimen 145 mm. in length, the depth is 6.5, showing the same ratio of proportion in their growth as *Dicrolene nigra*.

The ovaries (of 6005, A.M.N.H. 7502), a specimen measuring 310 mm. in length, are apparently identical in form and structure to the ovaries of *Dicrolene nigra* (A.M.N.H. 7510). They measure 27 mm. in length; 9.5 in depth; 13.5 in breadth. There are approximately 60 "stems" in each ovary and the eggs clustering upon these stems seem very much smaller and more numerous than the eggs of *Dicrolene nigra*.

At Station 84, Lat. 0° 17' S., Long. 91° 34' W., one mile north of Narborough Island of the Galapagos, in T<sub>2</sub> from a depth of 400 fathoms three specimens (Field no. 6386) A.M.N.H. 8454.

Although these specimens are small, the largest of them measuring from snout to the base of caudal, 33 mm., in width across the pectoral fin bases, 4.8, in depth between the pectoral fin bases, 7 mm. and in the diameter of eye, 1.5, they, nevertheless, agree so well with Garman's description of the adult *Mono mitopus torvus* that there is not much question of their belonging to that species. In general appearance and in all proportions and especially in the position and character of their ventrals, they agree perfectly, only differing as to fin count. Dorsal 96-101 as opposed to Garman: Dorsal 107-111; Anal 69-80 as opposed to Garman: Anal 86-95; and Caudal 12-13 as opposed to Garman: Caudal 8. As the caudal fins of these young specimens are not very clearly differentiated, however, this may account for the difference, for some of their rays that now seem to pertain to the caudal may later belong to the dorsal and anal fins respectively. They agree in the number of their pectoral rays as well as of their ventral.

While in the adult of the species the muciparous pores are rather vaguely indicated as holes or cavities under the skin, in these three young specimens

they are very clearly defined as holes in the loose skin of the head. They are arranged as follows: three anterior to the origin of the maxilla, the first in front of and under the anterior nostril, the second close beside the first, still under the anterior nostril but more on the slope of the premaxilla, while the third is slightly in front of and below the posterior nostril. The fourth little hole is below the anterior border of the orbit. And on the lower jaw there are four open pores, the first placed beneath the second one of the series on the upper jaw, and the other three occurring in equidistant succession, the last of the four being situated well behind the posterior edge of the maxilla.

The anterior nostril of these young specimens is distinctly tubular in form, whereas the anterior nostril of *Monomitopus trovus*, the adult, is described as being upon a tumid prominence. But young and adult agree in having the anterior part of their lateral lines emphasized and in the suggestion of threefoldness of these lateral lines.

In color these three specimens are of a rather dark brown, agreeing better with the adult specimens than with the immature specimens (those averaging 140 mm. in length), and they show no indication of any blueness. And the inside of their mouth and branchial chambers is white instead of the forget-me-not blue characteristic of the specimens from Station 74. Two of them, however, display vague, broad bars of a slightly darker brown running, vertically, about three of them in the body tract. While the third specimen exhibits no such ornamentation.

At Station 87, Lat. 0° 00', Long. 91° 53' W. in T<sub>3</sub>, from a depth of 450 fathoms, one specimen, measuring 33 mm. and agreeing in every particular with the three young individuals from Station 84. In color this specimen agrees with the one from Station 84 that gives no indication of darker cross bars on the brown of its muscular tract.

#### ***Cherublemma* gen. nov.**

Body and head compressed. Clavicular bones produced, meeting under the eye. Ventral fins close together on the humeral symphysis, originating on a vertical, slightly anterior to the posterior edge of the orbit, and consisting of 2 pairs of bifid rays. Pectorals broad, simple. Vertical fins united. Large, flat opercular spine, no preopercular spines. Gill membranes not united, free from the isthmus. Eye lateral, fairly large. Snout moderate, blunt. Nostrils rather large and close together in the centre of the side of the snout. Mouth wide, oblique.

#### ***Cherublemma*<sup>9</sup> *lelepris*<sup>10</sup> sp. nov.**

Type. At Station 26, Lat. 5° 03' N., Long. 81° 08' W. in T<sub>4</sub> from a depth of 140 fathoms, one specimen (Field no. 5108) A.M.N.H. 8463.

Length from snout to base of caudal, 33 mm. Depth between pectoral fin bases, in length, 4.7; width, between pectoral fin bases, in length, 11.5; body cavity, from tip of snout to vent, in length, 2.5; head, in length, 5.5. Head, from tip of snout to posterior border of operculum, 6.5. Snout in head, 4.5;

<sup>9</sup> Lemma = a subject for discussion or doubt.

<sup>10</sup> Lelepris = an unknown fish mentioned in Pliny.





Fig. 32. *Cherublemma telepris* gen. et sp. nov.

From a drawing in colors by Isabel Cooper.

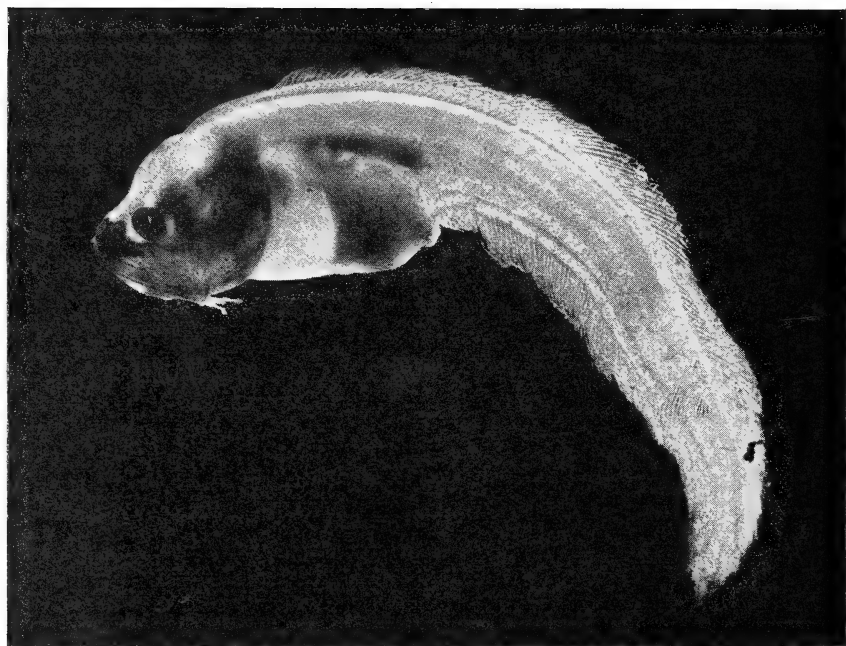


Fig. 33. *Cherublemma telepris* gen. et sp. nov. Station 26 in T<sub>4</sub> from a depth of 140 fathoms (A.M.N.H. 8463). From a photograph of the type specimen.

eye, 5; mouth, from anterior edge of premaxillary to posterior edge of maxillary, 5; longest dorsal ray, 1.5; anal ray, 3.5; pectoral ray, 2.5; ventral ray, 2; caudal, 3.5.

Brr.? D 118-120 A 85-87 P 24-25 V 2 bifid rays C 8-9.

Body compressed, elongate, tapering gradually to a narrow caudal. Snout blunt, not projecting at all beyond lower jaw. Profile like a pug-dog's, forehead above anterior edge of orbit rising abruptly and then continuing in a gradual slope to the origin of the dorsal fin. Mouth large, terminating, on a vertical, behind the orbit, by a space equal to  $\frac{3}{4}$  of the diameter of the orbit. Teeth small, conical, irregularly and rather widely placed along the edge of the premaxillary. Eye fairly large, equal to the interorbital space. Nostrils conspicuous, placed nearer to each other than the anterior nostril is near to the eye, or the posterior to the snout. Gill membranes not united, free from isthmus. Operculum with a broad flat spine at its upper edge. Origin of dorsal above the base of the pectoral; of the anal at a distance 1.1 in head behind the base of the pectoral. Dorsal rays longer than those of anal, the bases of both fins extending to caudal, which is not very conspicuously differentiated and consists of 8 or 9 rather short rays. The ventrals arise from the humeral symphysis on a vertical from the anterior edge of the pupil of the eye; their bases close together. Each ventral fin consists of two rather stout rays that become freely bifid at a distance of about 2 mm. from their base. The pectoral rays are simple and the fin broad and rounded in outline. Of any lateral line there is only a faint trace on the "shoulder" above and behind the top of the operculum.

Color in alcohol: body and head cream colored with scattering of dark pigment "stars" more frequent on the head which still retains too a yellow tinge about the operculi. Fins white, except for the tips of the vertical fins which are dusky. Eye: iris dark blue.

Color in life: Body faintly tinged with lemon chrome that becomes stronger on the head and anterior body. On the head, snout, nape and opercula, a definite pigmentation, a sprinkling of pomegranite purple. Eye: iris pale green. Base of unpaired fins white, their tips dusky. Pectorals and ventrals white.<sup>11</sup>

This genus *Cherublema* may be fitted into Smith and Radcliffe's key,<sup>12</sup> the most recent arrangement of the genera of the brotulids, as follows:

a' Sirembinae

Clavicular bone greatly produced, meeting below eye; ventral fins inserted under eyes, behind tip of humeral symphysis.

b' Preopercle unarmed; snout without sharp spine at tip; head entirely scaled; ventral simple. . . . . *Sirembo*.

b'' Ventrals consisting of 2 pairs of bifid rays. . . . . **Cherublemma**.

b<sup>2</sup> Preopercle with 3 spines; snout with a sharp spine—head practically naked, ventrals bifid. . . . . *Hoplobrotula*.

<sup>11</sup> During the process of examination one of the ventral fins of this specimen A.M.N.H. 8463 was torn off, most unfortunately. The remaining ventral is in good condition, however, and clearly shows the two bifid rays. While it was still intact this fish had a most conspicuous pair of ventrals, rays below its chin, 8.

<sup>12</sup> "Description of Fishes of the Families Brotulidae, etc. . . . from the Philippine Islands and the Dutch East Indies. 'Albatross' 1907-1910." By H. M. Smith & Lewis Radcliff. Proc. U. S. Nat. Mus., vol. 44.

a<sup>2</sup> Neobythitinae.

Position of humeral symphysis normal behind eyes, etc.

*Cherublemma lelepris* then, is closest to the genus *Sirembo* "Bleeker, 22;<sup>13</sup> orthotype *Brotula imberbis*—T. & S. There is a good description of this genus as represented by *Brotula imberbis* (now *Sirembo imberbis*) in *Fauna Japonica*.<sup>14</sup> Our fish differs from this description in: the character of the ventrals, of the mouth and teeth and the size of the eye; in fin counts and color. It, however, agrees better with it—and not only on account of the position of the ventrals—than with any of the Neobythitinae in which sub-family most of the known genera and all of the other genera of brotulids taken on the *Arcturus* belong.

*Imberbis* is the only species known of this genus *Sirembo* as limited by Gill, for "Vallant's *Sirembo* is a congeries of heterogeneous forms, including, probably, the representations of three subfamilies."<sup>15</sup>

And on account of this paucity of representation and because this specimen (Field no. 5108, A.M.N.H. 8463) is, by no means, an adult individual, I have been very loth to believe that it did represent a new genus. And were it not so widely different—and yet not with differences that seem of purely larval extravagance—I should not have ventured to consider it with seriousness. But, although I have been able to find nothing in the literature concerning larval or young brotulids, I think I have perceived, through studying five specimens of brotulids, 33 mm. and smaller, that were taken on the 'Arcturus,' enough characters typically brotuloid that persist with stability in these young stages upon which to base my notion that *Cherublemma lelepris* by departing from them marks itself as unique.

Of these young *Arcturus* brotulids one in particular (Field no. 630 A.M.N.H. 8464) from Station 86, in T<sub>4</sub> from a depth of 800 fathoms, a specimen measuring 22.2 mm. in length, gives rather significant indications of these characters that I believe may be considered stable. In proportions, fin counts and other characters this specimen foreshadows any of six or seven genera of the sub-family Neobythitinae, and therefore it has been impossible to determine it; but it is unmistakably brotuloid and has most of the conventional characters of the Neobythitinae in perfect miniature, including general proportions, a sharp opercular spine, large nostrils, the anterior one close to the tip of snout, the posterior to the orbit; ventrals consisting of a pair of simple filaments close together behind the humeral symphysis and slightly forward of the base of the pectorals. It seems significant, too, that the four other specimens, 33 mm. and under should possess the characteristic ventrals, opercular spines and general body shape.

I have been careful, however, to impute to *Cherublemma* no characters, that, from what I learn from these young individuals, may not have generic value, such as the color, the abruptly rising forehead and in particular the teeth. That these teeth,—small, conical, and rather widely and irregularly placed along the premaxillary,—are on the way to becoming villiform seems not improbable,

<sup>13</sup> Bleeker 1858. cr. "The Genera of Fishes," by David Starr Jordan. Leland Stanford Junior Univ. Pub. Univ. Series, 1919. Part II.

<sup>14</sup> "Fauna Japonica," by Temminck & Schlegel. 1850, p. 253, pl. CXI, fig. 3.

<sup>15</sup> "Oceanic Ichthyology," by Goode and Bean. P. 340.

especially since the teeth of the tiny brotulid, A.M.N.H. 8464, (22.2 mm. in length) resemble them.

#### SUMMARY

We have seen that within the species *Dicrolene nigra*, of 6 adults, all of the gravid females are, in general, dark blue, and of the individuals without eggs one is dark blue and the other two are brown. And of 23 immature but fairly large specimens, 7 are conspicuously dark and the other 16 are lighter, though by varying degrees, as though they presaged the adult color differences.

Within the species *Monomitopus torvus*, among 31 adults, all of the 15 gravid females are a dark brown and their scales—those few not torn off in the nets—of a deep blue; and of the 16 adults without eggs, 4 are dark and 12 are, though by varying degrees, lighter, while their scales except those about the bases of the fins are not blue.

In *Porogadus breviceps* there are none but immature specimens with which to compare the one gravid female.

In *Lamprogrammus illustris*, the gravid female is distinctly blue while the specimen without eggs is brown. This individual, however, is perhaps too immature for its color to be of significance.

From this evidence, however, it seems true that there is a sexual color difference among at least two species of two genera of Brotulidae.

But why such a variation should occur among fish that live below the 600 fathom line, and usually deeper, is a problem apt to remain in as profound an obscurity as the depths themselves. For it seems reasonable to suppose that if these fish exhibited any sexual difference as an aid to recognition and courtship it would appear in the arrangement of the muciparus channels of the head and lateral line that are believed to be luminous, rather than by means of a coloration that must, one thinks, be indistinguishable to brotulid, if not to any eyes at that depth. A guess may be, perhaps, hazarded that color distinguishes the sexes of these bathybial species only as the expression of a recollection of an ancient littoral existence where courtship-colors were the rule. For these brotulids are inhabitants of the shallower abyssal depths where the obscurity may have acted as yet "only in relation to the sensibility of their retina, but not that of their skin."<sup>16</sup>

<sup>16</sup> "Observations anatomiques et biologiques sur quelques poissons des très grandes profondeurs marines," by Louis Roule. C. R. Mém. Soc. Biol. Paris, 1916, vol. 79.

Nor is it at present possible to tell from what littoral forms—"degraded blennies" or any other—the brotulids are descended, for all of the marine brotulids are, at this stage in their history, abyssal and have no relatives that live where they can be observed, with the exception of some fresh-water cave-dwelling brotulids that have transparent skins without pigmentation, and eyes dwindling and even sunk under the skin of their heads. There are two species of very deep-dwelling marine brotulids that parallel the degeneration of these cave species. And, indeed, the brotulids are the Deep Sea Fishes par excellence, perfect examples of: "Those out-of-date forms of life which can no longer compete with the vigorous shore-dwelling races, and are compelled to retreat to the fresh waters on the one hand, or to the deep sea on the other."<sup>17</sup>

Nor are there any fossil records of these refugees from the stress of shallow waters. If the family Brotulidae is of the Order Anacanthini it is of an Order that is entirely absent from the whole Cretaceous period.

If anything were known about the method of reproduction in the family Brotulidae some light might be shed upon the causes of this color variation that exists among some of them, slight though it may be. But although some brotulids are known to be viviparous and more are known to be oviparous, that is all.

Are their eggs pelagic or demersal? It may be pertinent here to say that Gilchrist<sup>18</sup> believes that the eggs of several genera of macrurids are pelagic and rise to the top of the water after they are laid, unless, indeed, he says, the pressure and the salinity in opposition to one another hold the eggs motionless in a mid-vertical area!

Is there a breeding season among the brotulids and with it a vertical migration? Certainly the largest haul of brotulids on the *Arcturus*, most of the fish being gravid females, came from the "shallower depths" of Station 74, 625 fathoms; while in the dredges from 844 to 833 fathoms there were but two brotulids—one in each dredge—and neither of these carried eggs.

It is generally, if vaguely, supposed that young brotulids live nearer to the surface than do the adults, and all of the young brotulids of the *Arcturus* were taken comparatively near the surface.

<sup>17</sup> "The Antiquity of Deep Sea Fish Fauna," by A. Smith Woodward. *Natural Science*, 1898, vol. 12.

<sup>18</sup> "The Reproduction of Deep Sea Fishes," by J. D. F. Gilchrist. *Annals & Magazine of Natural History*, 1921, 9th ser., vol. 7, p. 173.

This may imply that brotulid eggs are somewhat if not entirely pelagic, and if such is the case, it is not extravagant to suppose that the adults themselves migrate upward to lay their eggs above the depths where pressure might prevent the free eggs from rising. For, if their recollection of a littoral existence is still strong enough to cause a variation of color between the sexes, it might also be strong enough to remind them of the seasons that once influenced their habits.

Finally, out of a family numbering 44 genera and more than 100 species, is anything of their life history known save the meagre facts here recorded? It is to be hoped, and is the purpose of this paper, that these *Arcturus* brotulids may arouse the interest of specialists who will discover and elucidate more facts concerning the life history and phylogenetic relationships of this interesting family.



# ZOOLOGICA

## SCIENTIFIC CONTRIBUTIONS OF THE NEW YORK ZOOLOGICAL SOCIETY

DEPARTMENT OF TROPICAL RESEARCH  
ARCTURUS OCEANOGRAPHIC EXPEDITION

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VOLUME VIII. NUMBER 4

Department of Tropical Research Contribution Number 249

GALAPAGOS BRACHYURA

BY LEE BOONE



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# THE LITTORAL CRUSTACEAN FAUNA OF THE GALAPAGOS ISLANDS.\*

BY LEE BOONE

Part I: Brachyura

(Figs. 34-102C incl.)

The Crustacean collections secured by the Arcturus Oceanographic Expedition, of the Department of Tropical Research, New York Zoological Society, under the directorship of Dr. William Beebe have proven so comprehensive a representation of the fauna of the regions explored that it has been deemed advisable to report upon the major faunal regions separately.

One of the most interesting collections secured by the expedition is that of the littoral Brachyuran crustacean fauna of the Galapagos Islands, which forms the subject of this paper. The *Arcturus* Expedition secured forty-six of the sixty-nine species of Brachyuran crabs that inhabit the littoral zone of the Galapagos archipelago, making the collection the largest of its kind ever brought from the islands by a single expedition. Of these forty-six species, five are new species, nine establish the first Galapagan record of species hitherto known only from the west Mexican-Panamic faunal regions, contributing a further bit of significant evidence of the probable past relationship of these islands to the mainland; five species are representatives of rare Galapagan forms, three of which have been hitherto known only from the types, which are no longer extant.

The value of the collection has been inexpressibly augmented by the extensive field-notes on the little known habits of these animals, made personally by the director of the expedition, Dr. William Beebe. His indefatigable industry in securing a large series of specimens has brought to light many interesting facts upon the unknown life cycles of these crabs. Identifiable zoea or megalops of eight Galapagan crabs were obtained, in addition to large masses of eggs and developing embryos of twenty-one species. The significance of this item is more fully appreciated when it is recalled that the life histories of less than a dozen species of American Brachyurans are known.

\* Contribution, New York Zoological Society Department of Tropical Research, No. 249.

The series of exquisite, photographically accurate color plates of many of the species, made under the direction of Dr. Beebe, by Miss Isabel Cooper, scientific artist of the expedition, has contributed much valuable data to a phase of carcinology usually ignored. Since it is impractical to publish all of these color plates, I have endeavoured to transcribe the data, using Ridgway's "Color Standards and Color Nomenclature" to interpret the color terms.

The preparation of this report has so emphasized the scattered literature of the Galapagan Crustacea obtained by the many previous expeditions, that, in an effort to render it of greater service, the scope of the present paper has been extended to include a description and illustration of every species of Brachyuran crab known from the littoral fauna of the Galapagos. The littoral, as distinguished from the deep-sea fauna, is here taken to include those species found from the shore down to a depth of 100 fathoms. It is fully realized that there is no such arbitrary line dividing the littoral from the deep-sea fauna; however, the few Galapagan Brachyurans taken below the hundred fathom line have their affinities with typical deep-sea forms, and while one or two such species have been occasionally taken above the one hundred fathom zone, they are omitted from the present report, for the above reason. In several instances, the absence of material for examination has made it necessary to quote the type description and copy the original illustration; full acknowledgment of this is made under each species so treated.

The photographs of the *Arcturus* and *Noma* crustaceans were made by Mr. John Tee-Van, assistant to the director, and Mr. Floyd Crosby.

The line drawings were made by Miss Isabel Cooper, with the exception of figures 39, 40, 41, 46, and 47, which were made by Mrs. Helen Damrosch Tee-Van, and figures 21, 26, 54, 74 and 102A, B, and C, by Mrs. John Gregory.

Mr. Serge Chetyrkin, preparateur of the Tropical Research Station, has made a careful preliminary separation of the many groups of thousands of crustaceans that comprise the *Arcturus* collection. I am especially indebted to him in connection with the present paper for the painstaking counting of thousands of crab eggs and larvae necessary to determine the potential offspring of a species.

In connection with the preparation of this paper, I have enjoyed

full privileges of study in the biological laboratory and library of the American Museum of Natural History. I am also indebted to Dr. Alex Wetmore, in charge of the United States National Museum, for the loan of three Brachyuran crabs obtained by the Harrison Williams Galapagos Expedition.

I wish to thank Dr. Beebe, the Director of the Department of Tropical Research, for the splendid facilities he has given me to prosecute this work. His suggestions and criticisms have been invaluable. I hope this account will serve as a reliable monograph of the crustacean fauna of Galapagos, and increase the interest in that amazing archipelago.



Order: DECAPODA  
Suborder: REPTANTIA  
Tribe: BRACHYURA  
Subtribe: BRACHYGNATHA  
Superfamily: OXYRHYNCHA  
Family: MAJIDAE  
Subfamily: INACHINAE

Genus *Stenorynchus* Lamarck, 1818

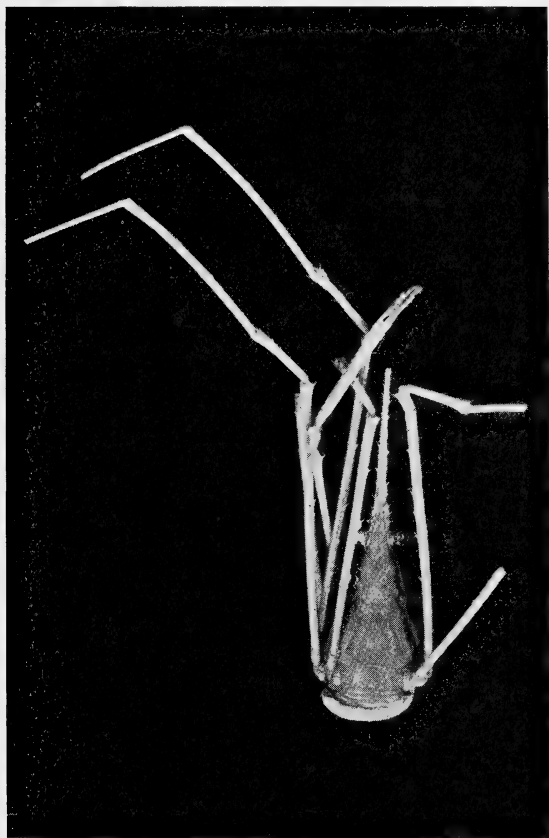


Fig. 34. *Stenorynchus debilis*  $\times 1\frac{1}{2}$ .

*Stenorynchus debilis* Smith. (Arrow Crab).

*Leptopodia sagittaria* Milne Edwards and Lucas, d'Orbigny's *Voy. l'Amer. Merid.*, vol. 6, pt. 1, p. 3, 1843; atlas vol. 9, *Crust.*, pl. 4, figs. 3-3c, 1847; Valparaiso; not *L. sagittaria* Leach;—A. Milne Edwards, *Crust. Rêg. Mex.* p. 172 (part) 1878; Miers, *Challenger Rept.*, vol. 17, p. 4 (part) 1886.

*Leptopodia debilis* Smith, *Rept. Peabody Acad. Sci.* 1871, p. 87, for 1869 and 1870, appendix 1871; Rathbun, *Proc. U. S. Nat. Mus.*, vol. 17, p. 44, 1894; Faxon, *Mem. Mus. Comp. Zool.*, vol. 18, p. 5, 1895.  
*Leptopodia modesta* A. Milne Edwards, *Crust. Rég. Mex.* p. 173, 1878.  
*Stenorynchus debilis* Rathbun, *Proc. U. S. Nat. Mus.*, vol. 21, p. 568, 1898: vol. 38, p. 570, 1910; *Proc. Washington Acad. Sci.* vol. 4, p. 283, 1902: *Bull.* 129, *U. S. Nat. Mus.* p. 18, pls. 4 and 5, 1925.

**Diagnostic Characters.**—Chelipeds much shorter, with proportionately longer fingers, than *Stenorynchus seticornis*. Rostrum about as long as the carapace. There is a small spine at the extremity of the basal antennal article.

**Type.**—Professor Smith's type came from the Bay of Realejo, Nicaragua, and is deposited in the Museum of Comparative Zoology, Cambridge, Mass.

**Galapagos Distribution.**—Four males and one female were taken at Tagus Cove, Albemarle Island, by the Hopkins-Stanford Expedition; one specimen from Tower Island, *Arcturus* station 37.

**General distribution.**—Gulf of California, Mexico, Nicaragua, Panama and the Galapagos Islands.

**Material examined.**—One specimen (broken) from Tower Island, Station 37, taken by the *Arcturus*.

**Technical description.**—Carapace convex, smooth, finely setiferous; branchial regions tumid. The rostrum is nearly twice as long as the carapace, and is cylindrical, tapering, slender, setiferous distally; there is a row of short spines arming each side of the rostrum. There is a strong acuminate spine on the basal antennal segment. Just behind the orbit there is a pair of similar spines, one on each side.

The chelipeds, one of which is broken in my specimen, are said by Prof. Smith to be equal. They are slender extending almost to the distal end of the carpal joint of the first ambulatory legs. The ischium is armed with a few spines on the inner side; the merus is much longer than the ischium, but not quite so long as the palm of the propodus, and is slender, cylindrical, armed with a series of spines along both lateral margins and with three more prominent spines on the inner distal margin; the carpus is short with a few spines on the outer lateral margin, and two spines at the inner distal angle; the palm is cylindrical, smooth, rather finely tomentose; the fingers are nearly as long as the hand, moderately channelled longitudinally, nearly straight except at the tips, which are curved inward; sparsely setiferous. The cutting edges of the fingers meet and are dentate proximally, finely serrate distally.

The ambulatory legs are long, slender, cylindrical and armed with spinules. The first pair of ambulatories are about six and one-half times as long as the carapace.

The female abdomen is very similar to that of *S. seticornis*. The male abdomen is said by Prof. Smith to have the third segment the broadest of the series, while the terminal article is composed of the completely anchylosed sixth and seventh segments.

#### Genus *Podocheila* Stimpon, 1860

##### *Podocheila margaritaria* Rathbun.

*Podocheila margaritaria* Rathbun, *Proc. Washington Acad. Sci.* vol. 4, p. 283, pl. 12, fig. 12, 1902; *Bull.* 129, *U. S. Nat. Mus.* p. 43, pl. 15, pl. 209, fig. 1, 1925.

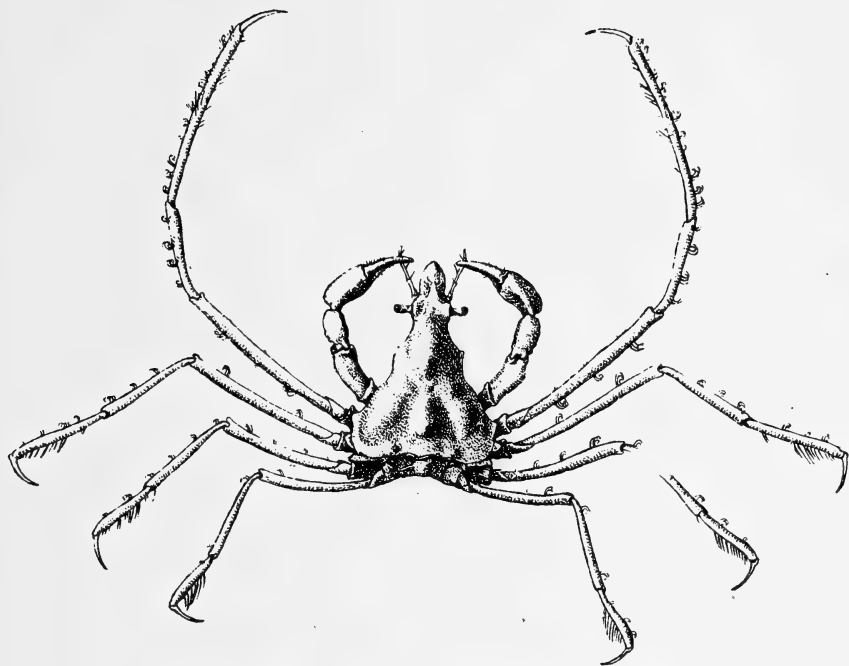


Fig. 35. *Podochela margaritaria*, male  $\times 2$  (After Rathbun).

*Diagnostic Characters*.—"Rostrum hood-shaped, carinate. No postorbital lobe. Sternum coarsely granulate. Fingers of adult male narrowly gaping." (Rathbun).

*Type*.—One male specimen was taken at Tagus Cove, Albemarle Island, Galapagos Islands, in 12 fathoms, by the Hopkins-Stanford Galapagos Expedition and is deposited in the United States National Museum.

*Galapagos Distribution*.—Known only from four specimens taken at Tagus Cove, Albemarle Island.

*General Distribution*.—Known only from the type-locality.

*Technical Description*.—The following is a copy of Miss Rathbun's description of this species:

"Ventral surface covered with coarse, pearly granules; dorsal surface inconspicuously granulate, especially on the depressed portions and the branchial regions. A high conical tubercle on the cardiac and on the gastric region. Rostrum long, hood-shaped, the hood thin, sharply cristate on median line. No postorbital lobe. Hepatic region small, swollen, converging to a small, downward-pointing tubercle. A similar pterygostomian tubercle. Sternal segments high closely covered with white granules, and separated by deep smooth depressions; two tubercles in front of the abdomen terminate ridges leading upward between which is a deep trough.



Basal antennal article narrowed anteriorly, deeply concave, lateral margins prominent. Chelipeds moderately roughened, chiefly on the margins, a few tubercles on the carpus, manus swollen, fingers narrowly gaping except near the tips. Legs of moderate length, first pair two and a half times length of carapace, dactylus short, slender, curved, propodus five times as long as dactylus. Remaining legs respectively twice, one and two-thirds and one and a half times the carapace length; dactyli of similar length and curvature, the second a little slenderer. Propodites distally thickened and bent upward, the amount of thickening increasing from second to fourth leg. The second propodus is two and a half times its dactylus, the third twice, and the fourth a little less than twice its dactylus.

*Measurements*.—Male, holotype, length of carapace 15, width 11 mm."

Genus *Dasygygius* Rathbun, 1897

Key to the Galapagos species of the genus *Dasygygius*.

Carapace convex, rostrum bifid.

*gibbosus*

Carapace depressed; rostrum simple, entire.

*depressus*

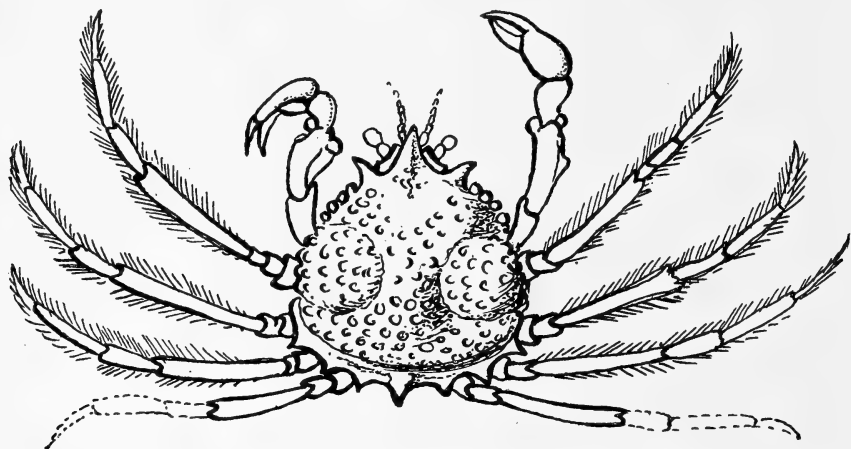


Fig. 36. *Dasygygius gibbosus*, male  $\times$  about 2 (After Bell).

*Dasygygius gibbosus* Bell.

*Microhynchus gibbosus* Bell, *Proc. Zool. Soc. London*, vol. 3, p. 88, 1835; *Trans. Zool. Soc. London*, vol. 2, p. 41, pl. 8, figs. 1-1c, 1836.

*Neorhynchus gibbosus* A. Milne Edwards, *Crust. Rég. Mex.* p. 187, 1880.

*Dasygygius gibbosus* Rathbun, *Proc. U. S. Nat. Mus.*, vol. 38, p. 571, 1910; *Bull.* 129, *U. S. Nat. Mus.* p. 138, pl. 274, figs. 1-4, 1925.

*Diagnostic Characters*.—Carapace rather flat; rostrum simple, triangular; ambulatory legs decreasing in length in the following order: 3, 2, 4, 1 pairs.

*Type*.—The type of this species was taken by D. Cuming at the Galapagos Islands. Known only from type specimen.

*Galapagos Distribution*.—Galapagos Islands.

*General Distribution*.—Galapagos Islands.

*Material Examined*.—None.

*Technical Description*.—The following is Bell's description of the type:

"The carapax is broadly pyriform, gibbous, rounded; the regions elevated, and separated by rather deep furrows; the surface covered, particularly on each branchial region, with numerous distinct rounded tubercles resembling very minute pearls. The *rostrum* is very small and bifid. The orbits are wide, and have a hollow at the outer side for the lodgment of the eyes when at rest, though not deep enough to conceal them entirely. A small fissure divides the upper margin of the orbit from the *rostrum*, and another externally from the tooth of its outer angle. The eyes are larger than their peduncles.

The external *antennae* are half as long as the body, the basilar joint as long as the *rostrum*, with a tooth at the outer angle. The internal *antennae* are lodged in a single cavity, open in front, bounded above by the *rostrum*, and on each side by the basilar joint of the external *antennae*. The pedipalps resemble those of *Camposcia*, excepting that the second joint of the inner foot-stalk is more heart-shaped, and deeply notched for the attachment of the moveable palp, which is long and greatly developed.

The *abdomen* of the male (the only sex yet observed) has seven joints, each of which has an elevation in the center: the first, which is wholly apparent when the animal is viewed from above, is somewhat quadrate, with a small tubercular tooth in the centre; the second very short; the third much broader than the rest, and the remainder abruptly narrower.

The first pair of legs are thicker than, but not much more than half as long as the others; the surface granulated; the hand rounded, and terminated by arched fingers which meet only at the *apex*, where they are denticulated. The four posterior pairs of legs are on the average nearly twice the length of the body, diminishing in the order 3, 4, 2, 5. They are cylindrical and hairy; and the nails are long, slender, and but slightly arched.

The general colour of the specimen is yellowish white.

Length of the carapax 6 lines; breadth 5 lines.

"One specimen only, a male, was obtained by Mr. Cuming at the Gallapagos Islands in sandy mud at six fathoms depth."

*Dasygygius depressus* Bell.

*Microhynchus depressus* Bell, *Proc. Zool. Soc. London*, vol. 3, p. 88, 1835;

*Trans. Zool. Soc. London*, vol. 2, p. 42, pl. 8, figs. 2, 2d-f, 1836.

*Neorhynchus depressus* A. Milne Edwards, *Crust. Rég. Mex.*, p. 187, 1880.

*Dasygygius depressus* Rathbun, *Proc. U. S. Nat. Mus.*, vol. 21, p. 570, 1898; vol. 38, p. 571, 1910; *Bull. 129, U. S. Nat. Mus.* p. 138, pl. 1; pl. 274, figs. 5-8, 1925.

*Diagnostic Characters*.—"Carapace depressed, granulate; rostrum small, triangulate, entire." (Bell.)

*Type*.—The type of this species was taken at the Galapagos Islands by H. D. Cuming. It is believed to be no longer extant.

*Galapagos Distribution*.—Galapagos Islands (type-locality).

*General Distribution*.—Galapagos Islands and Gulf of Lower California.

*Material Examined*.—None.

*Technical Description*.—The following is Mr. Bell's description of the type:

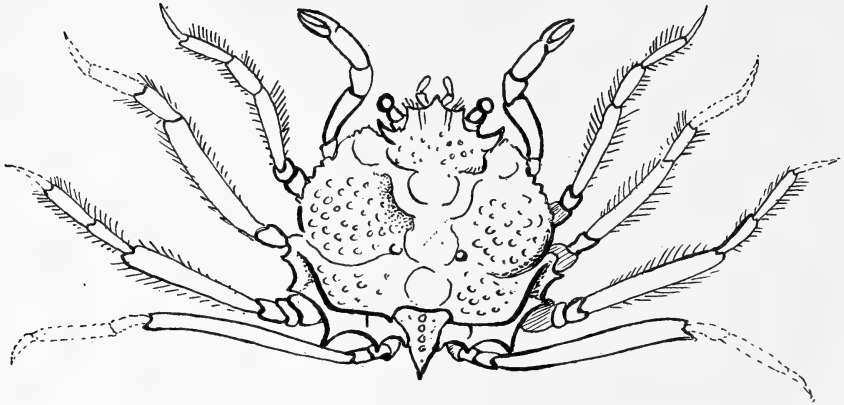


Fig. 37. *Dasygyius depressus*, female  $\times$  about 2 (After Bell).

"This very singular species differs greatly in general form and aspect, no less than in more minute detail, from the former. The carapax is much broader, suborbicular, very depressed, although the specimen is a female, and the regions, though sufficiently distinct, are but little elevated. The surface is covered with numerous minute granular elevations, with here and there a few larger ones. The orbits resemble those of *Micr. gibbosus*, excepting in being much larger, as are also the eyes. The rostrum is very small, triangular, and entire, the margins minutely granulated.

The tooth of the basilar joint of the external *antennae* is incurved at the point. The internal *antennae* resemble those of the former species, but their cell is still more open. The first joint of the inner footstalk of the external pedipalps is longitudinally channelled; the second joint cordiform, but less deeply notched than in *Micr. gibbosus*.

The sternal disc (in the female) is almost orbicular, and not nearly covered by the *abdomen*, which is five-jointed. The first joint is somewhat bell-shaped, with a long central tooth or spine projecting directly backwards; the second, third and fourth, extremely short; and the fifth, consisting of a perfect union of the last three joints, forms a flat orbicular disc, having a broad, depressed, longitudinal elevation.

The first pair of legs is, in this sex, extremely small; the arms much curved; the fingers very slightly arched, and minutely toothed towards the extremity. The remaining legs are similar to those of the former species.

Colour nearly white, but with a very slight pinkish tinge.

Length of the carapax 6 lines; breadth the same.

Of this species one specimen only, a female, was procured by Mr. Cuming with the former (*D. gibbosus*).

## Subfamily: ACANTHONYCHINAE

Genus *Acanthonyx* Latrielle, 1825*Acanthonyx petiverii* A. Milne Edwards. (Shield Crab; Kelp Crab).

- Acanthonyx petiverii* H. Milne Edwards, *Hist. Nat. Crust.*, vol. 1, p. 343, 1834; Dana, *U. S. Expl. Exped.*, vol. 13, *Crust.*, pt. 1, p. 128, 1852; *atlas*, pl. 5, fig. 6a-d, 1855; A. Milne Edwards, *Crust. Rég. Mex.*, pl. 27, figs. 7-7f, 1878; Rathbun, *Bull. U. S. Fish Comm.*, vol. 20, for 1900, pt. 2, p. 60, (1901); *Proc. U. S. Nat. Mus.*, vol. 38, p. 534, pl. 46, fig. 4, 1910.
- Acanthonyx emarginatus* Milne Edwards and Lucas, *d'Orbigny's Voy. l'Amer. Merid.*, vol. 6, pt. 1, p. 9, 1843; *atlas*, vol. 9, pl. 5, fig. 2, 1847.
- Acanthonyx debilis* Dana, *Amer. Journ. Sci.*, ser. 2, vol. 11, p. 272, 1851; *U. S. Expl. Exped.*, vol. 13, *Crust.*, pt. 1, p. 127, 1852; *atlas*, pl. 5, fig. 5 a and b, 1855.
- Peltinia scutiformis* Dana, *Amer. Journ. Sci.*, ser. 2, vol. 11, p. 273, 1851; *U. S. Expl. Exped.*, vol. 13, *Crust.*, pt. 1, p. 130, 1852; *atlas*, pl. 5, fig. 7a-c, 1855.
- Acanthonyx concamerata* Kinahan, *Journ. Roy. Dublin Soc.*, vol. 1, p. 334, pl. 14, fig. 1, 1857.
- Acanthonyx petiverii* Stimpson, *Ann. Lyc. Nat. Hist. New York*, vol. 10, p. 97, 1871; A. Milne Edwards, *Crust. Rég. Mex.*, p. 143, and synonymy, 1878.
- Pugettia scutiformis* Miers, *Challenger Rept.*, vol. 17, p. 40, footnote, 1886; Moreira, *Arch. Mus. Nac. Rio de Janeiro*, vol. 11, pp. 65 and 138, 1901; *Bull. Soc. Zool. France*, vol. 45, p. 126, footnote, 1920; Lenz and Strunck, *Deutsche Sudpolar Exped. 1901-1903*, vol. 15, *Zool.* 7, p. 276, 1914.
- Acanthonyx petiverii* Rathbun, *Bull.* 129, *U. S. Nat. Mus.*, p. 142, pl. 44, pl. 222, figs. 1-6, 1925.

*Diagnostic Characters*.—Carapace shield-shaped with an obtuse preorbital tooth, a large hepatic lobe and two small branchial lobes.

*Type*.—Professor Milne Edwards' type specimen, which is deposited in the Paris Museum, is recorded as coming from the "Antilles."

*Galapagos Distribution*.—Galapagos Islands (Bell); *Arcturus* station 54, off Hood Island, depth 15 feet.

*General Distribution*.—This fascinating little dweller in the submarine plants of the tidal zone, has a wide distribution, ranging from southern Florida, through the Bahamas, West Indies, Yucatan and Carribean southward as far as Rio de Janiero on the Atlantic coast and from Lower California southward, including the Galapagos Islands, down to Valparaiso, Chile.

*Material Examined*.—Two male specimens of this species were secured by the director of the Expedition, William Beebe, while diving in fifteen feet of water at Station 54, off Hood Island.

*Color*.—This species has evolved a coloration which is a perfect mimicry of the rust-brown seaweed in which it dwells. The carapace and legs are mottled fawn-color to rust-brown and flecked with golden yellow and black maculations.

*Habits*.—*Acanthonyx petiverii* spends the greater part of its adult life cradled in the branches of seaweed and similar marine plants of the tidal zone. The secret of its ability to withstand the tremendous force exerted by wind and wave is best understood by an examination of its powerful subchelate legs, which have been so remarkably modified to meet the needs of such an existence. Experience has taught me that the only way to collect specimens of this species *with the legs on* is to take the plant or branch to which they cling also. They are very poor swimmers. If the plant to which they cling is snipped away with a pair of scissors and they are successfully shaken out of their aquatic "treetops," they

will crawl and clumsily paddle their way to the nearest plant shelter. Upon attaining this they vanish with mesmeric gracefulness into the foliage and finding a point of vantage, fasten their eight anchor-toes to the twigs and pendulum with the submarine "treetops" as they sway with the waves. This little species is largely herbivorous, grazing on the algae and similar small plants, although it sometimes eats the tender new growths of the larger seaweeds. It is carnivorous, also, feeding on young amphipoda, zoea, small worms and tiny mollusks.



Fig. 38. *Acanthonyx petiverii*,  $\times 3\frac{1}{2}$ .

It takes *Acanthonyx petiverii* about an hour and twelve to twenty minutes to cast off its old hardened shell and emerge as a "soft" crab. This is a particularly interesting process, executed by a series of unbelievably graceful movements, as the tiny legs are successively slipped from the old encasement, the carapace cracks along the line of the sternal sutures and with elfin daintiness, the little creature slips out clad in a delicate soft-hued, soft-tissued replica of its old dress. It seeks a sheltered branch to which it fastens the eight little anchor-toes, now relatively soft and less able to function than usual, and thus hidden, so far as it is possible to hide from the incessant menace of the keen-eyed hunger-driven enemies, the second phase in the process of ecdysis takes place. In this cumbersome, technical phrase is concealed the story of one of the most marvelous bits of natural history. Like the mythical gnome of ancient fairy lore, who emerges from the seed-pod and swells and swells, until a giant stands revealed, so *Acanthonyx petiverii* swells and

swells and swells,—inscrutably, inexplicably, without apparent cause or motion, but visibly enlarging, expanding until when a matter of 14 to 23 minutes of such miracle has elapsed, one discovers that *Acanthonyx petiverii* not only appears larger, but scientific measurement with calipers and millimeter reveals that an increase in size of 35 to 54 per cent. has actually occurred. The next few hours are also devoted to concealment, during which time the soft shell becomes paper-like and brittle and subsequently calcifies. Nothing is eaten by the soft-shelled creature, save possibly the minutae sieved during its incessant rhythmic "bubbling" of seawater. The day after the shell has been cast or approximately 20 to 24 hours thereafter, the new carapace is quite hardened, the tips of the chelipeds especially so, and impelled by hunger, the little creature climbs from its sanctuary into the submarine treetops, there to resume the daily routine of crab existence.

In the subtropical waters of southern Florida, I have taken females bearing eggs and embryos from February through the year to the following January, but breeding seems dominant from February to April, during which period it is difficult to find an adult female without eggs. One female measuring only 8 mm. long diameter, 5 mm. short diameter, carried 472 fertile eggs. Another measuring 19 mm. long diameter, 12 mm. short diameter, carried approximately 1200 eggs. These are globular, minute, dirty yellow to brown in color. The larval stages of this species have not yet been successfully studied.

*Technical Description.*—Carapace shield-shaped, moderately convex, longer than wide, frontal region triangular, rostrum short, squarish, bifid, deflexed, margined with stout upward directed setae. Preorbital lobes angulated, bent upward and outward, setiferous. Anterolateral angles prominent, flaring; two small subequal teeth on the lateral margin of the branchial region, one near the anterior of the mesobranchial margin and the other near the posterior of the metabranchial margin; the posterior margin is rounded.

There are three obscure tubercles on the gastric region, one on the cardiac and one on the intestinal region. These tubercles are poorly developed, occasionally obsolete in the males and usually absent in the females. The abdomen in both sexes has the fourth and fifth segments coalesced. Eyes small, approximately under the preocular lobes; stalks stout, swollen; cornea very weak, outward directed. The antennae have the basal article smooth, simple, the second and third articles subcylindrical, extending as far forward as the apex of the rostrum, the flagellum is exceedingly slender.

The chelipeds are massive for so small a species; the basis and ischium are quite small; the merus long, three-sided, the distal apices of the lateral margins are produced as three spines—that of the dorsal being most acute. The carpus is less than half the length of the merus and is quite convex.

The ambulatory legs successively decrease in length from first to fourth pairs. All are stout, laterally compressed, have the proximal joints small, the merus long, the carpus little more than half as long as the merus and dilated distally, the propodus decidedly dilated, the distal margin concave and produced at the free angle as a blunt tooth against which the dactylus fits claw fashion; this distal margin of the propodus is densely setiferous; the dactyl is moderately stout, curved, pointed, finely spinose and setiferous on the inner margin

which is appressed to the curved surface of the propodus. The distal margins of the basal, meral, and carpal joints are also set with tufts of setae.

Genus *Taliepus* A. Milne Edwards, 1878

*Taliepus marginatus* (Bell).

*Epialtus marginatus* Bell, *Proc. Zool. Soc. London*, vol. 3, p. 173, for 1835 (1836); *Trans. Zool. Soc. London*, vol. 2, p. 62, pl. 11, fig. 4, 4i, 4j, 4k (female), pl. 13 (male) 1836. Heller, *Reise Novara, Crust.*, Wien., p. 5, 1865; Smith, *Trans. Connecticut Acad. Sci.*, vol. 2, p. 33, 1869; A. Milne Edwards, *Crust. Rég. Mex.*, p. 138, 1878; Miers, *Proc. Zool. Soc. London*, p. 66, 1881; Ortmann, *Zool. Jahrb., Syst.*, vol. 7, p. 42, 1893; Lenz, *Zool. Jahrb., Suppl.* 5, p. 756 1902; Rathbun, *Proc. U. S. Nat. Mus.*, vol. 38, p. 534, pl. 36, fig. 2, 1910; Aurivillius, *K. Svenska Vet.-Akad. Handl.*, vol. 23, p. 43, 1889.

*Epialtus (Antilibinia) marginatus* Miers, *Journ. Linn. Soc. London*, vol. 14, p. 650, 1879; Rathbun, *Proc. U. S. Nat. Mus.*, vol. 17, p. 69, 1894.

*Taliepus marginatus* Rathbun, *Bull.* 129, *U. S. Nat. Mus.* p. 164, pls. 52 and 53; pl. 220, fig. 2; pl. 221, 1925.

*Diagnostic Characters*.—Rostrum narrowed anteriorly and bifid; there is a small tooth on each side in front of the orbit; post-orbital tooth obsolete; propodites of legs armed below with one tooth.

*Type*.—In the preliminary, synoptic diagnosis of this species the type-locality is given as "the shores of Brazil," but in the first full diagnosis of the species Bell states that the material "was taken in the Galapagos Islands by D. Cuming and on the shores of Brazil by D. Miller." This material is believed to be no longer extant.

*Galapagos Distribution*.—Galapagos Islands (type locality).

*General Distribution*.—Galapagos Islands, Valparaiso, Chile, and shores of Brazil.

*Material Examined*.—None.

*Technical Description*.—The following is Mr. Bell's description of the type:

"The carapace is rounded behind but angular and produced forwards; the surface even, punctate; and the regions divided by impressed lines. The upper and under surfaces are separated by a distinct marginal line, on which are two small tubercles, of which the posterior is obsolete, or marked only by a slight turn in the marginal line. The anterior margin has two acute prominent teeth. The *rostrum* is narrowed forwards and bifid; and there is a small tooth on each side in front of the orbit. The orbits are circular and entire, and the eyes globular, accurately fitting the orbits and scarcely projecting beyond them.

The internal *antennae* are lodged in a large *fossa*, which is open and undivided anteriorly, but divided from behind forward by a long narrow spine. The external *antennae* are concealed by the *rostrum*; the basilar joint broad and much produced forwards; the moveable portion cylindrical, shorter than the rostrum. Pedipalps with the outer footstalk having parallel sides, except at the apex, which is triangular; inner footstalk smooth and polished, with the second joint truncated at the inner and posterior angle.

*Abdomen* of both sexes with seven joints.

Anterior feet of the male very robust, nearly twice as long as the carapax, very minutely granulated: the arm with two tubercles above and two beneath: the hand rounded, smooth; the fingers strongly tuberculated through their whole length, meeting only at the points, which are somewhat excavated; the

movable finger longer than the other. Posterior feet cylindrical, the joints tumid: the second pair longer than the hinder ones, which decrease in length to the fifth. A tooth on the inferior side of the penultimate joint, which is hairy at the point: it is smallest on the second pair and longest on the fifth. The last joint is curved, acute, and finely toothed beneath.

Colour of the adult, dark brown; of the young female, paler and reddish.

Length of the carapax 4 inches; breadth 3 inches 3 lines.

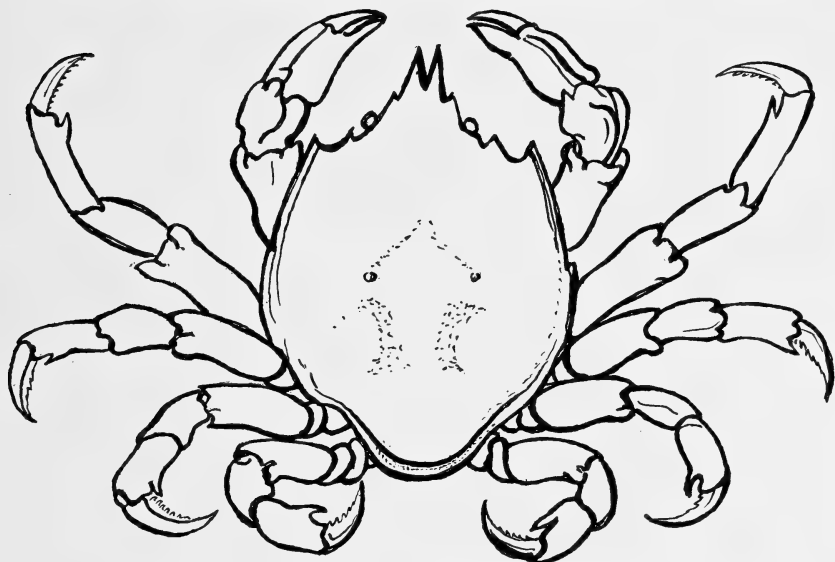


Fig. 39. *Taleipus marginatus*, slightly reduced (After Bell).

The large male specimen was found by Mr. Cuming with *E. dentatus* at Valparaiso in crevices of rocks. The young female specimen was brought by Mr. Miller from Rio Janeiro.

It is not without considerable hesitation that I have decided on giving to these *Crustacea* the characters of distinct species. I was first led to the opinion that they were so, by comparing with Mr. Cuming's specimens of *Epiattus* one of an immature female which was kindly presented to me by Mr. Miller, and which he had taken at Rio: and a subsequent more particular examination of the former specimens has tended greatly to confirm this view, as the largest and finest of them, a very fine adult male, possesses all the characters which had led me to consider Mr. Miller's specimen as distinct. I have thought it desirable to offer a figure of each of these two individuals, and as they differ from *Ep. dentatus* only in slight characters, which are easily appreciated, it appeared unnecessary to figure that species, especially as it had been described by my friend Dr. Milne Edwards, and will I hope shortly be figured by him.

The characters upon which I have founded this distinction are these. In *Ep. dentatus* the lateral margin is rounded, the sides of the carapax passing off



from above to beneath in a continuous rounded surface: in *Ep. marginatus* the upper and under surfaces are separated by a distinct slightly salient margin; the posterior tubercle, which in the former is very distinct, is in the latter only indicated by a very slight degree of prominence in the marginal line; and the lateral spine of the former is in the latter supplied by a tubercle. The very great difference in the size of the anterior feet probably depends on age: but it is worthy of notice that in the rest of the feet the inferior spine near the extremity of the penultimate joint, is much smaller and shorter relatively in *Ep. dentatus* than in *Ep. marginatus*."

Subfamily: PISINAE

Genus *Pelia* Bell, 1835

*Pelia pulchella* Bell.

*Pelia pulchella* Bell, *Proc. Zool. Soc. London*, vol. 3, p. 170, 1835 (1836); *Trans. Zool. Soc. London*, vol. 2, p. 45, pl. 9, figs. 2, 2d-2f, 1836; *Rathbun*, *Bull.* 129, *U. S. Nat. Mus.* p. 284, pl. 241, figs. 1-4, 1925.

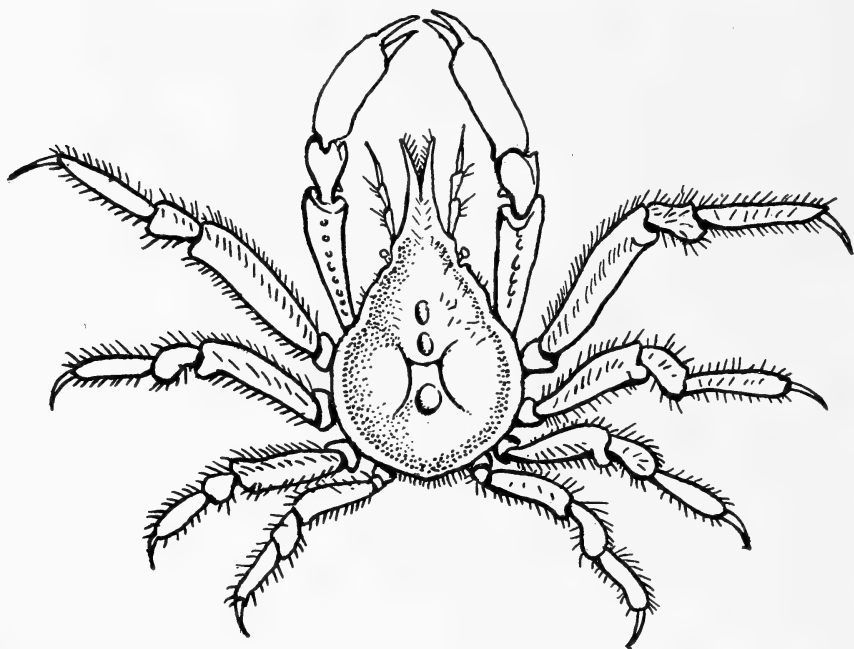


Fig. 40. *Pelia pulchella*, male  $\times$  about 4 (After Bell).

*Diagnostic Characters*.—Rostrum much produced, nearly half as long as the rest of the carapace, bifid at the extremity. Basal joint of the external antennae prominent dorsally.

*Type*.—Bell's type was taken in the Galapagos Islands by D. Cuming; it is no longer extant.

*Galapagos Distribution*.—Known only from the type specimen taken in the Galapagos Islands.

*Material Examined*.—None.

*General Distribution*.—Galapagos Islands.

*Technical Description*.—The following is Mr. Bell's description of the type:

"Carapax pyriform, gibbous, rounded, polished, somewhat hairy: the regions elevated, particularly the gastric and cardiac, the latter of which forms a rounded tubercle: lateral margin entire. *Rostrum* straight, much produced, nearly half as long as the rest of the carapax, bifid at the extremity, with a slight groove continued backwards from the bifurcation.

Internal *antennae* inserted at the base of the *rostrum*: external *antennae* placed at the sides of the *rostrum*; the basilar joint reaching to about half its length, almost wholly exposed above, slightly tapering towards its extremity, where there is a small external tooth; the moveable portion setaceous, extending a little beyond the *apex* of the *rostrum*, the second and third joints cylindrical, and much larger than the terminal portion. External pedipalps with the external footstalks semifusiform; the first joint of the internal footstalk elongate, rhomboid; the second joint of an irregular four-sided figure, the margins entire.

*Abdomen* in the male seven-jointed, the joints becoming gradually smaller from the third to the last.

Anterior feet longer than the body; the arm three-sided, having a toothed *carina* above, and two *carinae* beneath, the outer of which is minutely serrated; the hands slightly compressed, smooth: the fingers, when closed, in contact throughout their whole length, the half towards the *apex* being serrated, and a tubercle of the immoveable finger received into a corresponding excavation in the moveable one. The remaining feet compressed, carinated and hairy above, the second pair longer than the first, the rest becoming gradually shorter.

Length 4 lines; breadth  $2\frac{1}{2}$  lines.

A single male specimen was taken by Mr. Cuming from sandy mud, at a depth of sixth fathoms."

#### Genus *Pisoides* Milne Edwards and Lucas, 1843

*Pisoides edwardsii* (Bell).

*Hyas edwardsii* Bell, *Proc. Zool. Soc. London*, vol. 3, p. 171, 1835; *Trans. Zool. Soc. London*, vol. 2, p. 49, pl. 9, fig. 5, 1836.

*Pisoides tuberculatus* Milne Edwards and Lucas, *d'Orbigny's Voy. l'Amer. Merid.*, vol. 6, pl. 1, p. 11, 1843; vol. 9, atlas, pl. 5, figs. 1-1d, 1847; *Nicolet, in Gay, Hist. Chile, Zool.*, vol. 3, p. 134, 1849; A. Milne Edwards, *Crust. Règ. Mex.*, p. 75, pl. 16, figs. 5-5b, 1880; Lenz, *Zool. Jahrb., Suppl.* 5, vol. 2, p. 757, 1902; Rathbun, *Proc. U. S. Nat. Mus.*, vol. 38, pp. 572 and 616, 1910.

*Pisoides edwardsii* Dana, *U. S. Expl. Exped.*, vol. 13, *Crust.*, pt. 1, p. 87, atlas, pl. 1, figs. 2a and 2b, 1855; Miers, *Proc. Zool. Soc. London*, p. 63, 1881; Rathbun, *Proc. U. S. Nat. Mus.*, vol. 38, pp. 672 and 613, 1910; *Bull.* 129, *U. S. Nat. Mus.*, p. 285, pl. 236, 1925.

*Diagnostic Characters*: Carapace pyriform; preocular spine wanting; postocular spine prominent, acuminate. Rostral horns flat, basal antennal article with a prominent tubercle at its external distal angle; squarish.

*Type*.—Valparaiso, Chile and the Galapagos Islands; types not extant.

*Galapagos Distribution*.—Galapagos Islands (type locality).

*General Distribution*.—West Panama; Chile, southward to the Straits of Magellan; also the Galapagos Islands.

*Material Examined*.—None.

*Technical Description*.—The following is Mr. Bell's description of type:

"Carapax pyriform, elevated, posteriorly rounded, anteriorly narrow, but without a distinct contraction behind the orbits; covered with brown hair. *Rostrum* formed of two elongated compressed teeth slightly converging at the apex. Orbits spacious, without spines, having a triangular tooth of moderate side at the outer *canthus*. Eyes globular, larger than their peduncles.

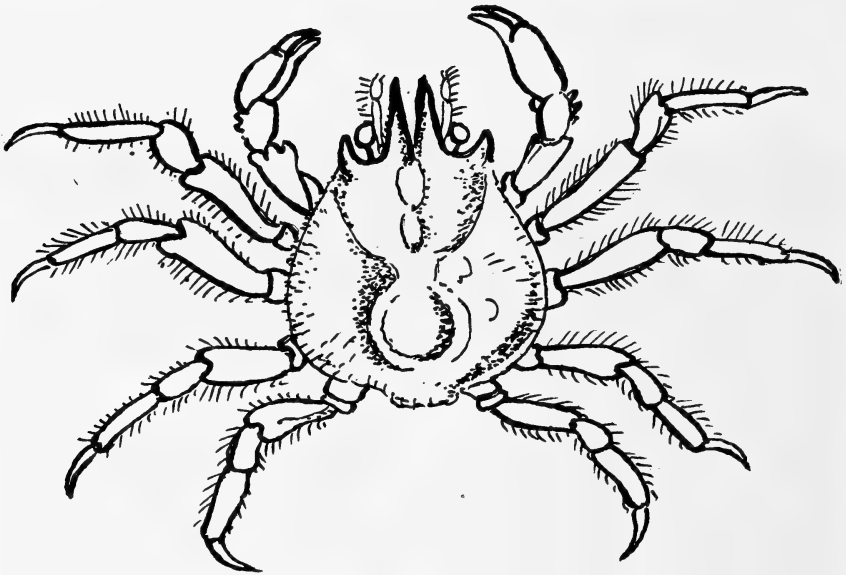


Fig. 41. *Pisoides edwardsii*,  $\times$  about 2 (After Bell).

Interior *antennae* lodged in a *fossa* at the base of the *rostrum*, which is open anteriorly, and undivided. Exterior *antennae* longer than the *rostrum*, very hairy, the basilar joint with raised margins; the second and third less expanded than in the other species of the genus. The pedipalps offer no peculiarity.

*Abdomen* of the male with the penultimate joint with a small tooth on each side.

Anterior legs in the adult male rounded, the hand much thicker than the arm, and terminated by curved fingers, which touch each other only at the apex, which is serrated; moveable finger with a single tubercle near the base. In the female the hands are scarcely longer than the arms, the fingers are less curved, and there is no tubercle. The remaining legs are somewhat flattened above, obtusely carinated beneath, and very hairy: the second pair is the longest, and they diminish regularly to the fifth.

In size the specimens from the two localities differ exceedingly. There are adult males from the Gallapagos Islands, of which the length is 6 lines and the breadth 4 lines. From Valparaiso I have examined a specimen of an im-

mature male, as appears by the want of development of the anterior feet, the length of which is 9 lines and the breadth 7 lines. This remarkable discrepancy led me at first to expect that I should discover some specific differences; but the most careful examination has convinced me that they are all of one species."

Genus *Herbstia* H. Milne Edwards, 1834

Merus of ambulatory legs armed with spines. Superior orbital margin with one tooth between the preorbital and post-orbital teeth.

*edwardsii*

Merus of ambulatory legs unarmed. Lateral margin of carapace armed with four minute teeth.

*pyriformis*



Fig. 42. *Herbstia edwardsii*,  $\times 3$ .

*Herbstia edwardsii* (Bell).

*Herbstia edwardsii* Bell, *Proc. Zool. Soc. London*, vol. 3, p. 170, 1835; *Trans. Zool. Soc. London*, vol. 2, p. 46, pl. 9, figs. 3, 3g-3i, 1836; Rathbun, *Bull. 129, U. S. Nat. Mus.*, p. 300, pl. 105, figs. 3 and 4; pl. 240, figs. 1-4, 1925.

*Herbstiella edwardsii* Stimpson, *Ann. Lyc. Nat. Hist. N. Y.*, vol. 10, p. 93, 1871.

This species was dedicated to Prof. A. Milne Edwards by Mr. Bell.

*Diagnostic Characters*.—Carapace depressed; superior orbital margin with

one tooth between the preorbital and postorbital teeth. Chelipeds of male more than twice as long as the post-frontal part of the carapace; palms smooth.

*Type*.—The type material, which is no longer extant, was taken in the Galapagos Islands by D. Cuming.

*Galapagos Distribution*.—Galapagos Islands (type-locality) also James Island (Hassler Expedition); off Hood Island, station 54, depth 15 feet, *Arcturus* Expedition.

*General Distribution*.—Known only from the Galapagos Archipelago.

*Material Examined*.—Four females, three of which are ovigerous, one male and one very young specimen were obtained by Dr. William Beebe while diving in 15 feet of water in Gardner Bay, off Hood Island.

*Technical Description*.—Carapace depressed, almost subcircular but somewhat narrowed in the postfrontal region; surface finely punctate, sparsely setigerous. There are four small tubercles placed in a transverse row on the higher part of the gastric region and several similar tubercles elsewhere on the carapace, especially on the high points of the branchial region and along the lateral margins. There are two transverse rows of tubercles on the intestinal region, the anterior row consisting of three tubercles. The frontal region is distinctive, the rostral horns are small, triangulate, pointed, somewhat flattened, being distinctly longer than the external spine of the basal antennal article and separated from each other by a deep V-shaped sinus. There is a longitudinal row of long hook-like hairs subparallel to their inner lateral margins. The orbit is large, defined by a superior preorbital tooth, a postorbital tooth and with a third small, rounded tooth beneath; there is a clearly defined hiatus between the latter and the basal antennal article. The basal antennal article is broad with the antero-external angle produced to an acuminate process which is outward and forward-directed and is not as long as the rostral horns; there is a smaller tooth behind the large one on the lateral margin; the second and third antennal articles are cylindrical, the last one reaching beyond the rostrum; the flagellum is composed of about sixteen rather long articles which are set with long spinose setae. The antennulae are rather stout and fold almost vertically within the septum beneath the rostral hood.

The chelipeds of the male are more than twice as long as the postfrontal region of the carapace; those of the female are almost twice as long as this region; the ischium is well developed and produced to a point on its inferior anterior distal margin; the merus is long and dilated distally; the carpus is convex, smooth; the propodus is elongated, nearly cylindrical, almost smooth, sparsely punctate; the fingers are less than half the total propodal length and are subequal with a wide gape; the basal finger has a strong tooth which fits between two teeth of the hinged finger. In the very young specimens and in the females these teeth are absent or much reduced in size.

The ambulatories are similar and successively decrease in length from the first to fourth pairs; all have the meral joint long and set with a row of small spines above; the carpus is elongated; the propodus is very slender and approximately as long as the merus; the distal end is produced on its posterior distal margin into an elongated rounded process which interfits and articulates with a similar but shorter, backward-directed process which arises from outer

proximal side of the dactyl; the dactyl is about two-thirds as long as the propodus and is slender, curved, acuminate. All the legs are sparsely setigerous.

*Herbstia pyriformis* (Bell).

*Rhodina pyriformis* Bell, *Proc. Zool. Soc. London*, vol. 3, p. 170, 1835 (1836); *Trans. Zool. Soc. London*, vol. 2, p. 44, pl. 9, figs. 1-1c, 1836.  
*Herbstia pyriformis* Stimpson, *Ann. Lyc. Nat. Hist. N. Y.*, vol. 10, p. 93, 1871; Rathbun, *Bull. 129, U. S. Nat. Mus.*, p. 301, pl. 104, figs. 2 and 3; pl. 240, figs. 5-8, 1925.

*Diagnostic Characters*.—Carapace pyriform, posterior margins decidedly produced; lateral margin with four minute teeth. Propodus of chelipeds with one spine. Ambulatory legs without spines or tubercles.

*Type*.—Bell's type was taken in the Galapagos Islands.

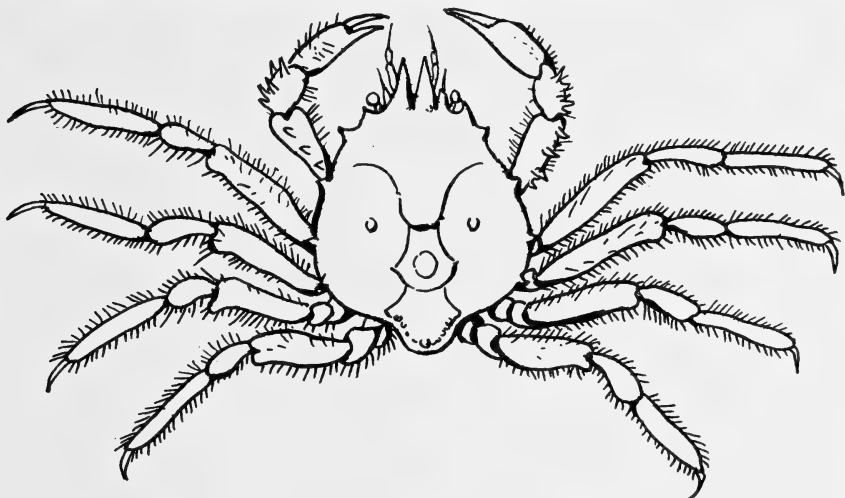


Fig. 43. *Herbstia pyriformis*,  $\times$  about 2 (After Bell).

*Galapagos Distribution*.—Galapagos Islands, type-locality, also James Island, (Hassler Expedition).

*General Distribution*.—Galapagos Islands and James Island.

*Material Examined*.—None.

*Technical Description*.—The following is Mr. Bell's description of the type:

"Carapax pyriform, somewhat depressed, the regions slightly and evenly elevated: rostrum about as broad as it is long, small, consisting of two pointed teeth; lateral margin with four distant, minute teeth: posterior margin produced. Orbits large, with a triangular hiatus above, and a tooth at the outer and inner canthus. Eyes large, globose, fixed on very short peduncles, which are small at their junction with the eyes, but larger at their insertion into the orbit.

Internal antennae lying in deep, circumscribed, longitudinal, somewhat lunulate cavities. External antennae twice as long as the rostrum, the basilar joint broad, bidentate, the outer tooth being the shortest, and placed further back, at the inner canthus of the orbit. The pedipalps were so much injured in the specimen as not to admit of description.

*Abdomen* of the male seven-jointed, decreasing in breadth from the third joint to the last.

The anterior pair of feet rather thicker but shorter than the others; the arm and wrist hairy and beset with small spines; the hand hairy above, but without spines; the fingers are slender, and are in contact throughout their whole length, and the margin is very minutely serrated. The remaining feet are longer than the carapax, the second pair by nearly one third; the remainder diminishing gradually to the fifth. They are nearly cylindrical, hairy but without spines or tubercles, and terminate in a small, slightly curved claw.

The colour of the only specimen known is pink, the hairs brown; the legs are whitish with pink annuli or bands; but as the specimen is considerably bleached and injured, it is impossible to judge of its natural colour.

Length of the carapax 8 lines; breadth 6 lines.

A single male specimen only, probably immature, was procured by Mr. Cuming, at the depth of six fathoms, on coral sand. It had evidently been long dead."

Genus *Lissa* Leach, 1815

*Lissa aurivilliusi* Rathbun.

*Lissa aurivilliusi* Rathbun, *Proc. U. S. Nat. Mus.*, vol. 21, p. 575, pl. 41, fig. 4, 1898; *Proc. Wash. Acad. Sci.*, vol. 4, p. 284, 1902; *Bull.* 129, *U. S. Nat. Mus.*, p. 333, pl. 246, fig. 2, 1925.

*Diagnostic Characters*.—"Branchial ridge narrow; postero-lateral margin concave; one crest on carpus of first three pairs of ambulatory legs." (Rathbun).

*Type*.—One male from off Cape St. Lucas, Lower California, *Albatross Station* 2829; deposited in the United States National Museum (Cat. No. 21575).

*Galapagos Distribution*.—One male specimen was taken on a reef north of Tagus Hill, Tagus Cove, Albemarle Island, by the Hopkins-Stanford Galapagos Expedition.

*General Distribution*.—Lower California, off Cape St. Lucas and Magdalena Bay; Galapagos Islands.

*Technical Description*: (After Rathbun): "Gastric prominence small, angular; oblique ridges leading from it sharp, finely tuberculate, with only a shallow tooth at middle in place of the round knob in *Lissa tuberosa* and terminating in a raised tooth at postero-lateral angle. Cardiac hump small, median ridge extending back from it narrow. Lateral margins tuberculate, a shallow tooth at middle and one farther back. Postero-lateral margin with a shallow sinus extending its whole length. Median notch of front shallow, outer teeth prominent."

"Chelipeds much as in *Lissa tuberosa*. Ambulatory legs with only one crest on the carpus of the first three pairs, the anterior crest of *Lissa tuberosa* being represented by a tooth.\* *Measurements*: Male, holotype, length of carapace 12.5, width 13 mm. Immature female, length of carapace 9.8, width 10 mm."

\*Dr. Rathbun gives the following description of the chelipeds of *Lissa tuberosa*:

"Chelipeds heavy in male; ischium with tooth on inner margin; merus with tridentate crest on superior margin; carpus with surface uneven, tubercle at

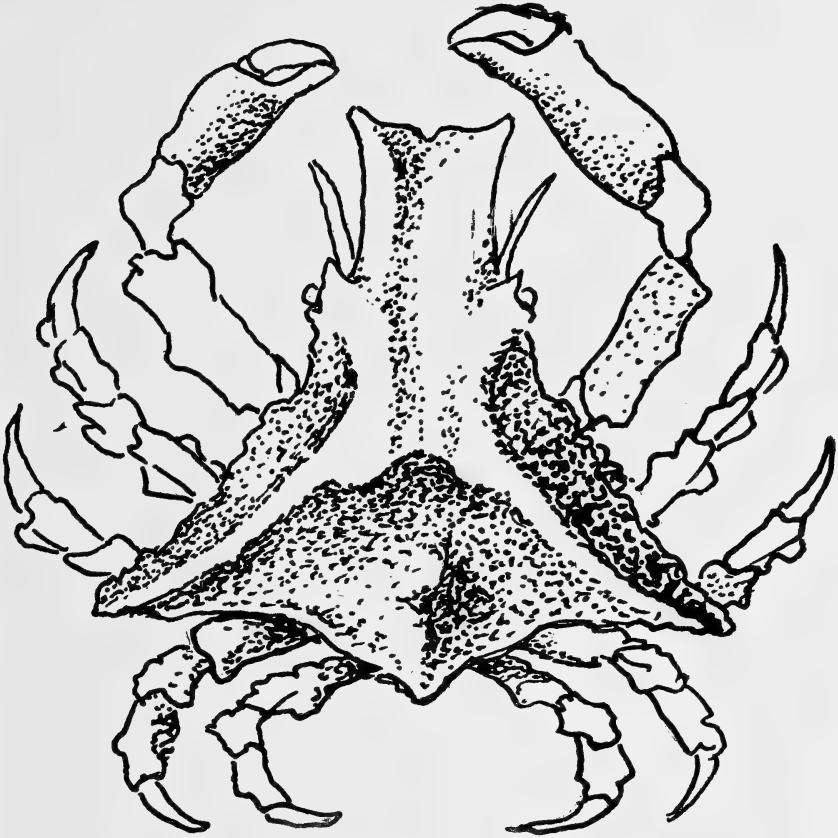


Fig. 44. *Lissa aurivilliusi*,  $\times 3\frac{1}{2}$  (After Rathbun).

inner angle. Hands broad, compressed, widening distally, inner surface tuberculate; lower margin of propodus with a sinus near its middle; dactylus with acute upper margin; fingers gaping for basal half. Chelipeds of female much smaller."

#### Subfamily: MAJINAE

#### Genus *Thoe* Bell, 1835

#### *Thoe erosa* Bell.

*Thoe erosa* Bell, *Proc. Zool. Soc. London*, vol. 3, p. 171, 1835; *Trans. Zool. Soc. London*, vol. 2, p. 48, pl. 9, figs. 4, 4k-4o, 1836; *Nobili, Boll. Mus. Zool. Anat. Comp. R. Univ. Torino*, vol. 16, No. 415, p. 30, 1901; not A. Milne Edwards, *Crust. R g. Mex.*, pl. 19, figs. 4-4d; 1875; p. 121, 1878, nor Rathbun, *Mem. Mus. Comp. Zool.*, vol. 35, p. 74, 1905; *Bull.* 129, U. S. Nat. Mus. p. 351, pl. 249, figs. 1-6, 1925.

*Diagnostic Characters*.—Basal segment of external antennae with one anterior tooth. Merus with two rows of deep excavations.



*Type*.—The type of this species was taken at the Galapagos Islands by D. Cuming.

*Galapagos Distribution*.—Galapagos Islands.

*General Distribution*.—Galapagos Islands; and Bay of Santa Elena, Ecuador.

*Material Examined*.—None.

*Color*.—Light yellowish brown above, paler beneath (Bell).

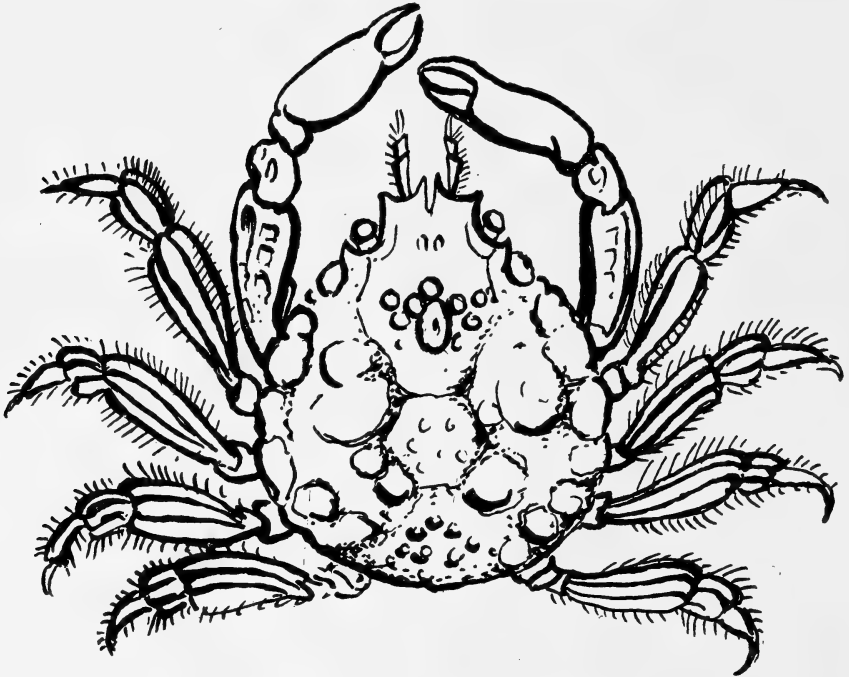


Fig. 45. *Thoe erosa*,  $\times$  about 2 (After Bell).

*Technical Description*.—The following is Mr. Bell's description of the type: "Carapax somewhat triangular, longer than it is broad, rounded behind, depressed, horizontal, covered with low tuberosities; the lateral margin without teeth, perpendicular. *Rostrum* minute, tapering to the point, which is slightly divided. Orbit nearly round, without teeth, with three small fissures, one above the inner *canthus*, another at the outer angle, and the third beneath. Eyes *subretractile*, globose, smaller than the base of the peduncle.

Internal *antennae* lodged in a *fossa*, which is anteriorly divided by a tooth projecting backwards and longitudinally excavated. External *antennae* with the basilar joint very broad, produced forwards and backwards, the moveable portion three times as long as the *rostrum*, ciliated on the inner side. External pedipalps with the outer footstalk expanded at the outer margin; first joint of the inner footstalk nearly rhomboidal, with entire margins, ciliated on the inner margin; second joint without any emargination for the insertion of the palp.

*Abdomen* in both sexes seven-jointed. In the male, the third to the sixth joints are scarcely broader than the first and second.

Anterior legs in the male longer and much more robust than the remainder. The arm with a series of quadrilateral excavations on the upper and outer surface diminishing backwards. Hands smooth, carinated beneath, the fingers meeting only at the point, not excavated or serrated, but with a single tubercle near the middle of the movable finger: remaining feet flattened above, longitudinally rugose, the sides furnished with rather long hairs; beneath rounded and smooth.

Colour light yellowish brown above, paler beneath.

Length 6 lines; breadth 5 lines."

#### Genus *Pitho* Bell, 1835

Key to the Galapagos species of the genus *Pitho*.

Carapace with five distinct anterolateral teeth in addition to the postorbital tooth.

*quinquedentata*

Carapace with six distinct anterolateral teeth in addition to the postorbital tooth.

*sexdentata*

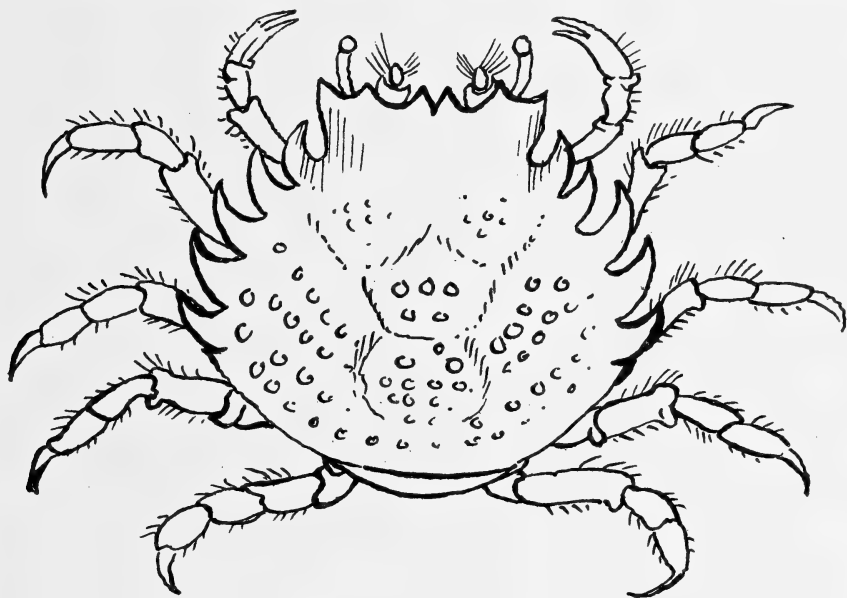


Fig. 46 *Pitho quinquedentata*, male  $\times$  about 3 (After Bell).

#### *Pitho quinquedentata* Bell

*Pitho quinquedentata* Bell, *Proc. Zool. Soc. London*, vol. 3, p. 172, 1835 (1836); Rathbun, *Proc. U. S. Nat. Mus.*, vol. 38, p. 573, 1910.

*Othonia quinque-dentata* Bell, *Trans. Zool. Soc. London*, vol. 2, p. 57, pl. 12, fig. 2, 1836.

*Othonia mirabilis* Gerstaecker, *Arch. f. Naturg.*, vol. 22, pl. 1, p. 113, (part), 1856.

*Othonia quinquedentata* A. Milne Edwards, *Crust. Rég. Mex.*, p. 118, pl. 24, figs. 3-3c, 1875.

?*Othonia aculeata* Cano, *Boll. Soc. Nat. Napoli*, ser. 1, vol. 3, p. 181, pl. 7, fig. 6, 1889.

*Pitho quinquedentata* Rathbun, *Bull.* 129, *U. S. Nat. Mus.*, p. 361, pl. 250, figs. 1-4, 1925.

**Diagnostic Characters.**—First movable segment of the external antennae narrowed. Cheliped with palm compressed, wide.

**Type.**—The type of this species was taken at the Galapagos Islands by D. Cuming.

**Galapagos Distribution.**—Galapagos Islands.

**General Distribution.**—Galapagos Islands and Bay of Panama.

**Material Examined.**—None.

**Technical Description.**—The following is Bell's description of the type:

"This species resembles the former one in most of its characters. It differs, however, in the number of teeth on the lateral margin, and very considerably in size. The frontal portion of the carapax is more produced, and the surface more scantily granulated, and without spines. The two specimens of the former species are nearly an inch long, and are both evidently immature, as the *abdomen* is but very little developed. Those of the present species, which are very little more than half an inch in length, have the *abdomen* fully developed, being very prominent, and of a circular form.

The general colour is brown; the feet with alternate rings of reddish and brown.

Two female specimens were found by Mr. Cuming with the former."

*Pitho sexdentata* Bell.

*Pitho sexdentata* Bell, *Proc. Zool. Soc. London*, vol. 3, p. 172, 1835, (1836).

*Othonia sexdentata* Bell, *Trans. Zool. Soc. London*, vol. 2, p. 56, pl. 12, figs. 1-1d, 1836.

*Othonia mirabilis* Gerstaecker, *Arch. f. Naturg.*, vol. 22, pt. 1, p. 113 (part), 1856; Cano, *Boll. Soc. Nat. Napoli*, ser. 1, vol. 3, pp. 102, 182, 1889.

*Othonia sexdentata* Stimpson, *Ann. Lyc. Nat. Hist. N. Y.*, vol. 7, p. 192, 1860; A. Milne Edwards, *Crust. Rég. Mex.*, p. 117 (part), 1875.

\* *Pitho sexdentata* Rathbun, *Bull.* 129, *U. S. Nat. Mus.*, p. 367, pl. 130, fig. 1; pl. 250, figs. 5-9, 1925.

**Diagnostic Characters.**—Carapace oval, narrowed anteriorly, densely granulose. Six distinct anterolateral teeth in addition to the postorbital tooth.

**Type.**—The type of this species was taken at the Galapagos Islands by D. Cuming at a depth of six fathoms.

**Galapagos Distribution.**—Galapagos Islands.

**General Distribution.**—Cape St. Lucas, Lower California; Mexico; Galapagos Islands.

**Material Examined.**—None.

**Technical Description.**—The following is Mr. Bell's description of the type: "Carapax broadly oval, moderately elevated, the surface rough, granulated, and slightly hairy; the lateral margin with six flattened triangular, falciform teeth, the points acute and directed forwards; a ridge of prominent granulations over the posterior margin. *Rostrum* very small, bifid, with a small *sulcus* continued backwards from the division. Orbits with a broad triangular fissure above, the tooth on each side flattened and triangular, the outer one the larger. Eyes not larger than the peduncles, which are elongated, slender, projecting forwards and slightly curved inwards.

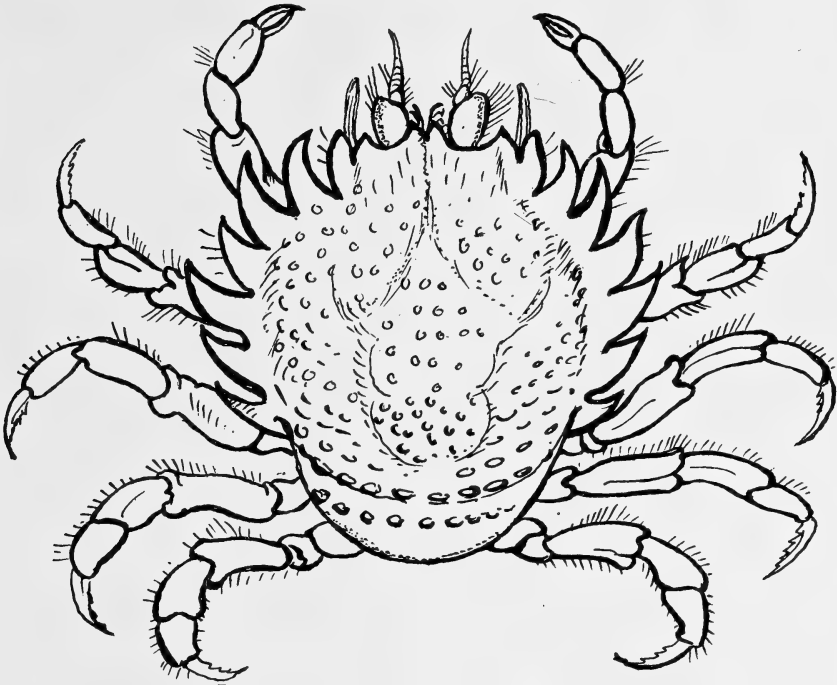


Fig. 47. *Pitho sexdentata*, female  $\times$  about 3 (After Bell).

Internal *antennae* extremely minute, and placed far back behind the rostrum. External *antennae* hairy, short, the basilar joint broad and flat, having a triangular external tooth, which extends forwards as far as that of the orbit; second joint flat, cordate anteriorly emarginate for the insertion of the third joint, which is also compressed, and much smaller than the previous one: the remaining joints are small and cylindrical. External pedipalps with the outer footstalk gradually acuminate: the inner footstalk with the first joint rather broad and rhomboidal; the second triangular with the anterior angles somewhat produced.

*Abdomen* (in the immature female) oval, consisting of seven nearly equal articulations, obtusely carinated along the centre; each of them delicately ciliated at its anterior margin.

*Feet* of moderate length: the anterior pair (in the female) considerably smaller than the rest, slender, slightly compressed, and smooth; hand with a small obtuse tooth above and one beneath, at the base; the fingers with the margins minutely serrated. The moveable finger longer than the other, and curved over its extremity. The remaining pairs of feet decreasing in length from the second to the fifth, depressed, and slightly hairy; the antepenultimate joint has a shallow *sulcus* on each side; the terminal joint is minutely toothed beneath.

Of the colour nothing can be said, as both the specimens preserved by Mr. Cuming were bleached."

Genus: *Mithrax* Latreille, 1817

Subgenus: *Mithrax*

Key to the Galapagos species of the subgenus *Mithrax*.

Lateral margin furnished with seven or eight sharp spines.	<i>spinipes</i>
Lateral margin furnished with four nodulose projections. Carpus with five tubercles on the inner margin.	<i>belli</i>



Fig. 48. *Mithrax spinipes*,  $\times 2$  (After Bell).

*Mithrax* (*Mithrax*) *spinipes* Bell.

*Pisa spinipes* Bell, *Proc. Zool. Soc. London*, vol. 3, p. 171, 1835, (1836);

*Trans. Zool. Soc. London*, vol. 2, p. 50, pl. 9, figs. 6, 6s, 6t, 6u, 1836.

*Nemausa spinipes* A. Milne Edwards, *Crust. Rég. Mex.*, p. 82, 1875.

*Mithrax* (*Nemausa*) *spinipes* Miers, *Challenger Rept.*, *Zool.*, vol. 17, p. 85.

*Mithrax* (*Mithrax*) *spinipes* Rathbun, *Bull.* 129, *U. S. Nat. Mus.*, p. 391, pl. 136, figs. 3 and 4; pl. 262, fig. 5, 1925.

**Diagnostic Characters.**—Lateral margin furnished with seven or eight sharp spines.

**Type.**—The type of this species was taken at the Galapagos Islands by D. Cuming, at the depth of sixteen fathoms.

**Galapagos Distribution.**—Galapagos Islands.

**General Distribution.**—From Gulf of California to Galapagos Islands and St. Elena, Ecuador.

**Material Examined.**—One female, from station 54, off Hood Island, Galapagos, taken by William Beebe, while diving in 15 feet of water.

**Technical Description.**—The following is Bell's description of the type: "This is an elegant little species, bearing considerable resemblance to young

specimens of *Pisa tetraodon* Leach, but differing in many essential particulars from this and every other known species.

The carapax is depressed and granulated; the lateral margin on each side beset with about seven or eight sharp spines, which are much smaller and shorter in the female than in the male. The former sex has a strongly-marked granulated line over the posterior margin, which is much less conspicuous in the male; a circumstance which I have observed in many species, not only of this but of several other genera. The tooth above the orbit, unlike many other species, is shorter than that of the basilar joint of the exterior *antennae*. The horns of the *rostrum* are separated throughout their length, and are somewhat divergent.

The *abdomen* of the male specimen was lost: that of the female is as broad as it is long, and has a low longitudinal *carina*.

The feet are all furnished with small spines, particularly on the third joint; the anterior pair in the female scarcely larger than the rest: those of the male specimen were lost.

This species differs from all the others, excepting *Pisa styx* Latr., in having numerous spines on the legs."

*Mithrax (Mithrax) belli* Gerstaecker (Purplish-brown Galapagos Spider Crab; Moss-back Spider Crab).

*Mithrax ursus* Bell, *Proc. Zool. Soc. Lond.*, vol. 3, p. 171, 1835 (1836); not *Cancer ursus* Herbst, 1788; *Trans. Zool. Soc. London*, vol. 2, p. 52, pl. 10, figs. 2, 2c, 2d, 2e, and 3, 1836; A. Milne Edwards, *Crust. Rég. Mexico*, p. 103, 1880.

*Mithrax belli* Gerstaecker, *Arch. f. Naturg.*, vol. 22, pt. 1, p. 112, 1856; name substituted for *Mithrax ursus* Bell; Rathbun, *Bull. 129, U. S. Nat. Mus.* p. 403, pls. 142 and 143, 1925; *Zoologica. N. Y. Zool. Soc.*, vol. 5, No. 14, p. 153, 1924.

*Diagnostic Characters*.—Color: Adults purplish brown; young, light brown, with reddish tinge. Dorsal surface of carapace mosaiced with flat granules; four projections of anterolateral margin nodulose; carpus with five tubercles on the inner margin.

*Type*.—The type locality given by Bell is "Galapagos Islands"; this type is said to be no longer extant.

*Galapagos Distribution*.—Galapagos (type-locality); Black Bight, Albe-marle Island; Chatham Island; Eden, Hood and Tower Islands.

*General Distribution*.—The recorded distribution of this species is restricted to the Galapagos Archipelago, where it has been taken by several expeditions, and a single record by Miers from Chile.

*Material Examined*.—Thirteen small, young specimens, secured by William Beebe, director of the Arcturus Oceanographic Expedition, while diving in 15 feet of water, at Station 54, Hood Island, Galapagos. One male specimen, taken at Station 37, in shore zone D to E, Tower Island, Galapagos Islands.

It was also taken by the Harrison Williams Galapagos Expedition.

*Technical Description*.—Carapace convex, subpyriform, maximum width a trifle more than length; the margins are thick, the protuberances nodulose; the dorsal surfaces mosaiced with flattened granules and irregular tubercles. The rostrum is bifurcated into two thick horns which are separated by a V-shaped sinus: two pairs of dorsal tubercles are present on the proximal part of the rostrum. There is a protrusion at the outer distal angle of the basal article

of the external antennae which is slightly incurved and somewhat higher and larger than either rostral horn. There is an inconspicuous preorbital lobe present, and two smaller tubercles on the orbital margin, one at the outer angle and one below. There are six tubercles on the lateral margin the first and second of which are quite large and each of which bear a smaller anterior tubercle, the hepatic tubercle is the second largest of the series; the most anterior of the simple tubercles is the largest, the fourth is the smallest, the fifth is of medium size and the sixth is postlateral. Behind the sixth tubercle there is a row of minor

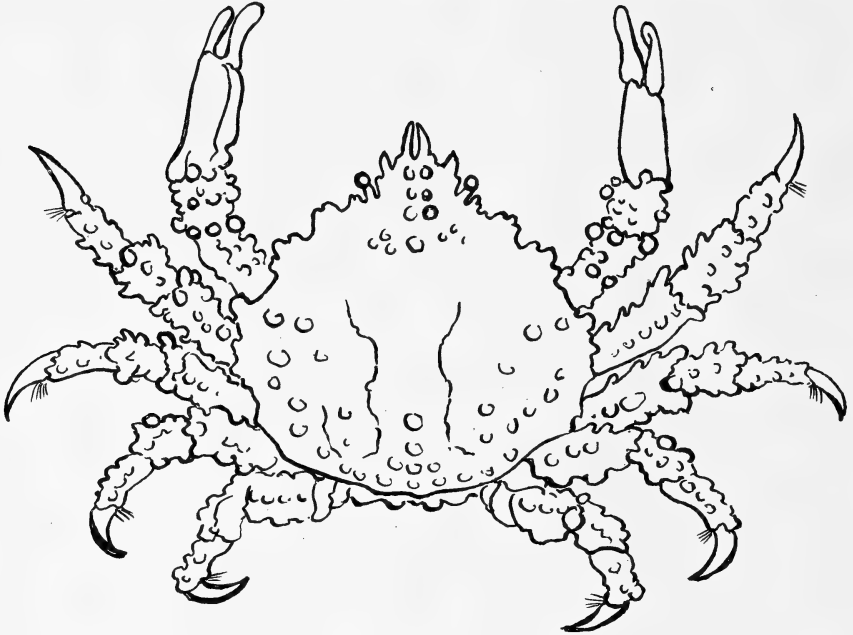


Fig. 49. *Mithrax belli*,  $\times 2$ .

tubercles on the posterolateral margin. There are two longitudinal rows, consisting of two or sometimes three small tubercles each, situated between and behind the orbits. Posterior to these there is a transverse row of five tubercles on the mesogastric region. There is also a row of tubercles on the lateral walls of the carapace, some of these are visible in a dorsal view. The pterygostomial ridge is coarsely granular or tuberculate. The regions of the carapace are distinctly delineated. The male abdominal belt is seven-segmented, triangulate with a rounded apex; the first pair of male appendages are moderately thick rods, curved basally, and directed straight forward within the cavity.

The external maxillipeds are rectangular, almost square, being only a little wider than long, and having the median and anterior portions decidedly protruberant. The exognath is not quite half as wide basally as long, extends to outer distal margin of the merus but is distinctly narrower and tapering for

its distal fourth; it bears a slender whip internally. The ischium is broadly rounded on the inner distal margin for more than half its width and produced beyond the outer distal angle, which is practically right-angled and gives rise to the merus which fits closely to the margin of the ischium, has its outer distal angle produced and its inner margin rounded. There is a strong depressed spine on the anterior margin of the merus, which is directed inward. The palp arises from an angulation about midway the anterior margin of the merus, and consists of three articles which successively decrease in size. The first and second articles curve around the margin of the merus; the third joint is very small and bears a brush of long setae. The inner lateral margins of the ischium are also finely setigerous.

The inner antennae are folded in the fossa beneath the rostrum; the basal joint is almost invisible; the first free joint is elongate, dilated, distally rounded on its outer surface and hollowed on its inner side for the reception of the next joint when folded; the second free joint is more robust than the first and is also convex on its outer surfaces and flat on the inner side; it bears distally the brief two-branched flagellum; the inner, stouter branch is about as long as the preceding article, and consists of a number of closely fused, tapering articles that bear on their outer side a dense brush of fine plumose setae; the slenderer, ventral branch is also shorter, consisting of six tapering articles each of which bears a few isolated setae on its distal margin.

The outer antennae have the basal article fixed, its outer distal angle is produced in a protuberance which is as large as either of the rostral horns; the first free joint is rectangular, about half as wide as the preceding segment and its width is equal to half of its own length; the third segment is slightly longer and distinctly narrower than the second segment; the flagellum is composed of five small articles, which taken together are conspicuously shorter than the club-like tactile organs which are borne along the distal and inner margin of the two free antennal segments. These organs are elongate, cylindrical, distally dilated and appear to have a central hollow cone within; the outer surface is finely setigerous.

The eyestalk is short, constricted below the cornea and produced beyond this constriction on the outer anterior side into a small rounded process which projects upon the cornea. The cornea is terminal, with its major range of vision a lateral one. The facets of the cornea are exceedingly fine and numerous.

The chelae (male) are slender, the three basal joints are subequal, not visible in a dorsal view. The merus is about one and one-half as long as the ischium and is dilated distally with the outer distal angle produced to a triangulate process; there is a prominent granulose tubercle on the upper surface near the inner distal margin and six tubercles on the inner distal margin; the carpus is short with the inner distal angle produced to a toothlike process, and the upper surface ornamented with six granulose tubercles; the propodus is slender, cylindrical, convex outwardly and slightly dilated and granulose near the base; the propodal finger is almost one-third of the length of the propodus and is spoon-shaped distally with this margin finely crenulate. The hinged finger is similar and subequal to the propodal finger; their tips are closely appressed on each other; there is a small gap between the cutting edges which are finely dentate.



The ambulatory legs are similar in structure. The first pair are as long as the chelae, the remaining pairs respectively decrease in size posteriorly, the second pair being shorter than the first by the combined length of one-half the length of the propodus and the dactyl; the third pair is shorter than the second pair and the fourth pair is shorter than the third by about this same ratio. Each leg terminates in a sharp curved dactyl and bears many club-like tactile organs along the outer and inner lateral margins. These are similar to those on the antennae. The larger adult crabs are said to be devoid of this growth.

#### Subgenus *Mithraculus* White

*Mithrax* (*Mithraculus*) *nodosus* Bell (Nobuled Crab).

*Mithrax nodosus* Bell, *Proc. Zool. Soc. London*, vol. 3, p. 171, 1835; *Trans. Zool. Soc. London*, vol. 2, p. 53, pl. 11, figs. 1-1b, 1836. *Mithraculus nodosus* White, *List Crust. Brit. Mus.*, p. 7, 1847; A. Milne Edwards, *Crust. Rég. Mex.*, p. 108, pl. 23, figs. 5-5d, 1875. *Mithraculus ruber* Cano, *Boll. Soc. Nat. Napoli*, ser. 1, vol. 3, p. 185, 1889. Not *Mithraculus ruber* Stimpson. *Mithrax nodosus* Rathbun, *Bull.* 129, U. S. Nat. Mus., p. 429, pl. 155, 1925.

*Diagnostic characters*.—Anterolateral margin with three large lobes. Posterior part of carapace rugose, worn-looking. The basal half of the inner margin of the cheliped is very thin and sharp.

*Type*.—Bell's type, which is no longer extant, came from the Galapagos Islands.

*Galapagos distribution*.—This species has been taken by the Hassler, the Albatross, the Hopkins-Stanford and the Harrison Williams Galapagos Expeditions and by Dr. W. G. Jones of the U. S. Navy, at James, Albemarle, Chatham, Hood, Charles, Duncan and Eden Islands of the Galapagos Archipelago.

*General distribution*.—Galapagos Islands; Miers also reports that there is a specimen of this species from Chile in the British Museum.

*Material examined*.—Six males, one of which is only 1.7 mm. wide, and one ovigerous female were collected at Station 54, off Hood Island, Galapagos, in 15 feet of water, by William Beebe.

*Color*.—Bell states that this species is brown above, paler beneath, with the hands dark plumbeous.

*Habits*.—It lives in the crevices of the coral rock and feeds upon amphipods, hermit crabs and other organisms. One specimen was captured eating a hermit, another with a half-devoured *Hyperid* amphipod.

*Technical description*.—Carapace 19 mm. wide, 16 mm. long. Rostral horns short, broad, rounded, separated by a deep V-shaped sinus which is fringed on both margins by long setae; there are a pair of subacute, submedian tubercles behind the rostrum and on a slightly higher plane situated between and in line with the anterior margin of the superior orbital lobes; between the bases of these orbital lobes there is a median node surmounted by a second pair of low submedian tubercles; posterior to these on the summit of the mesogastric area there is a transverse row of five subequal and subequally spaced tubercles. The anterolateral margin is divided into three node-like lobes, the first of which is close to the orbital angle, the second is slightly larger and the most prominent of the series. There is a small, subacute posterolateral lobe situated about as far behind the third anterolateral lobe as it is from the second

lobe. The cervical grooves are deeply delineated and sulci arising between the lateral nodes and running diagonally backward toward the outer give the carapace an eroded, granulose appearance. There are a number of rather large granulose tubercles on the posterior region of the carapace which bear elongated, club-shaped tactile organs. These latter have a central cone of deeper golden brown spongy fiber.

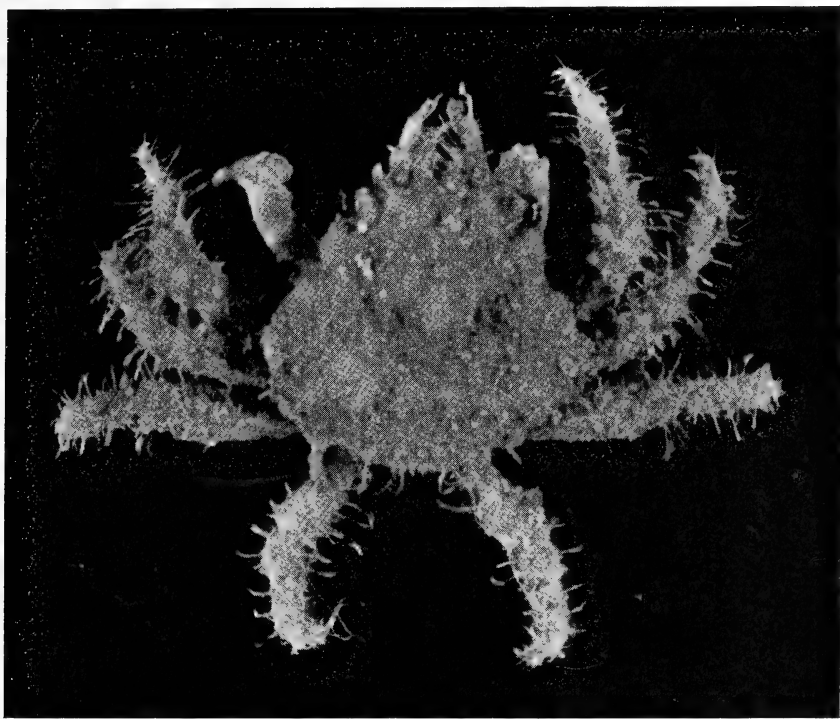


Fig. 50. *Mithrax nodosus*, young  $\times 4$ .

The female abdomen is seven-segmented, very broad, almost covering the entire sternal area between the legs; the second to fifth segments inclusive each bear paired biramose appendages, the outer branch of which is very heavily fringed and curves around the outer margin of the brood-pouch, forming a sieve-like wall around the eggs. The inner branch is shorter, two-jointed and beset with long setae to which the eggs are fastened.

The male abdomen is narrow, triangulate with the apex rounded, seven-segmented. The first pair of male appendages are slender rod-like processes which taper distally and are flattened into a minute two-pointed process which is channelled by a groove.

The eyestalk is rather small for the socket and is longitudinally striped with alternate bands of light and dark coloring. On its posterior distal margin it bears a long thick fringe of close-set setae which form a brush-like eye-lash; on its anterior distal margin it is produced to a narrow, rounded, tongue-like projection which does not reach to the middle of the cornea and is tufted with coarse setae at its apex; the cornea is spherical, composed of minute, hexagonal facets.

The internal antennae are rather small and fold vertically within the fossett which lies under the postrostral lobe. The basal joint is scarcely visible; the first and second free joints are subequal, rather compressed and dilated distally; the flagella are minute, the smaller branch consisting of four tapering rings and the larger one, of fourteen tapering annulations and a heavy brush of setae.

The external antennae have the basal joint anchylosed and its external distal angle produced to a prominent rounded nodule which is only slightly smaller than the rostral horns. The second (first free) segment arises from the inner half of the basal segment, is about half as wide as the latter, and is compressed cylindrical, somewhat dilated distally, with the inner distal angle slightly produced and bearing a fanlike arrangement of clublike organs which appear to be tactile; the third (second free) segment is about half as wide as and slightly longer than the second segment; it is laminate and armed with clublike organs similar to those of the preceding segment.

The external maxilliped have the exognath about three-fourths as wide basally as the ischium and narrowing a little distally and bearing an internal, slender, heavily fringed palp. The ischium is subrectangular but with the external distal border notched for the reception of the merus, and the internal distal fourth of the ischium broadly rounded and closely interfitted with the merus is declivous with its outer distal margin roundly produced and its inner margin evenly rounded; the palp arises from near the middle of the merus and consists of a broad, curved basal joint, a subcircular second joint and a small distal joint which is furnished with long plumose setae.

The chelipeds have the ischium produced triangularly on its anterior distal angle extending to the base of the big internal node of the inner meral margin; the merus is rather short and in addition to the inner node bears an outer forward-projected distal node and a rounded upper distal node, also two smaller upper nodes midway its length; the carpus is convex on its upper surface and bears six subequal nodes on this surface and has a node-like process midway on its inner margin; the propodus is somewhat compressed, laminate on the basal half of its inner margin, one-lobed; two lobes on its outer margin, and a tubercle on its upper surface; the fingers gape moderately, but meet at the weakly crenulated tips; the propodal finger is horizontal in position; the hinged finger has a single tooth about two-fifths of the distance from its base.

The ambulatories are similar in structure, but successively decrease in size posteriorly. They are coarsely nodulose, each nodule bearing a tuft of club-shaped organs which appear to be tactile, similar to those of the carapace and antennae.

*Mithrax (Mithraculus) denticulatus* Bell.

*Mithrax denticulatus* Bell, *Proc. Zool. Soc. London*, vol. 3, p. 172, 1835; *Trans. Zool. Soc. London*, vol. 2, p. 54, pl. 11, fig. 2, 1836; Nobili, *Boll. Mus. Zool. Anat. Comp. R. Univ. Torino*, vol. 16, No. 415, p. 31, 1901. *Mithraculus denticulatus* White, *List. Crust. Brit. Mus.*, p. 7, 1847; A. Milne Edwards, *Crust. Rég. Mex.*, p. 109, pl. 23, fig. 4m, 1875. *Mithrax (Mithraculus) denticulatus* Rathbun, *Bull. 129, U. S. Nat. Mus.*, p. 428, pl. 154, figs. 2 and 3, 1925.

*Diagnostic characters*.—Carapace nearly half wider than long. Two lobes and one spine on anterolateral margin. Two lobes of basal antennal segment equally advanced. Inner edge of wrist laminate.

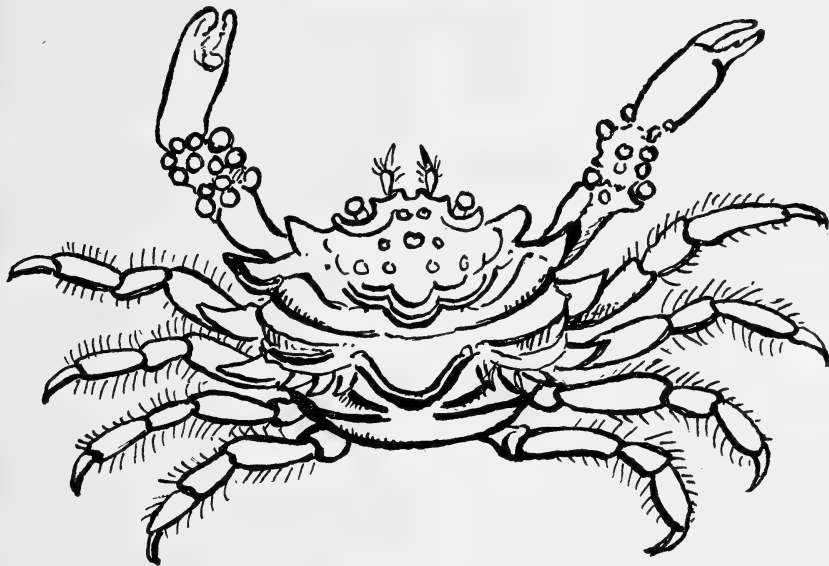


Fig. 51. *Mithrax denticulatus*,  $\times 2$  (After Bell).

*Type*.—Galapagos Islands, under stones. The type is no longer extant.

*Galapagos distribution*.—Galapagos Islands.

*General distribution*.—Lower California to Ecuador.

*Material examined*.—One taken at Cocos Island, May, 1925, by the *Arcturus*.

*Technical description*.—"A small species resembling in most of its characters the former one (*M. nodosus*), though differing sufficiently to be distinguished from it at the first glance. The markings on the carapax, though similar in situation, are much more distinctly and deeply incised; the teeth on the lateral margin, though rather obtuse, have not the rounded, tubercular character of the same appendages in *Mithr. nodosus*. The arms and the feet also are more sharply spined. But the character which at once distinguishes them, on a closer inspection, is the form of the second joint of the inner foot-stalk of the external pedipalp, which in *Mithr. nodosus* is crescent-shaped, and

much broader than it is long; and in the present species is cordate, and as long as it is broad.

Colour plumbeous, passing into fuscous.

Length 5 lines; breadth 6 lines.

Found by Mr. Cuming in considerable numbers with the former." The foregoing is taken from Mr. Bell's description.

Genus: *Telephrys* Stimpson, 1860.

Key to the Galapagos species of the genus *Telephrys*.

Three pairs of submedian tubercles forming a longitudinal series on the postrostral region. Four squamose tubercles forming a transverse row on the mesogastric region.

*diana*

Granules of carpace abundant, but not forming a definite pattern, one or two anterolateral, branchial, marginal spines present.

*tumidus*

*Telephrys diana*, sp. nov.

*Diagnostic characters*.—Three pairs of submedian tubercles forming a longitudinal series on the postrostral region. Four squamose tubercles forming a transverse row on the mesogastric region.

*Type*.—The type, an adult male and a female specimen, with additional material, were collected at station 54, off Hood Island, Galapagos Islands, by William Beebe, while diving in 15 feet of water.

*Galapagos distribution*.—*Arcturus* station 54, off Hood Island.

*General distribution*.—Known only from the type locality.

*Material examined*.—The type, an adult male and a female specimen, and 112 additional specimens, i. e., 50 males, 38 females, and 25 ovigerous females containing eggs, embryos and zoeae in practically all stages of development were collected at station 54, off Hood Island, Galapagos, by William Beebe, while diving in 15 feet of water. This series contains adults ranging in size from 1.9 mm. diameter to 10 mm. diameter.

*Technical description*.—Carapace 9.1 mm. long, 9.2 mm. greatest width, (across the urogastric sulcus); subovate, nearly subcircular; regions of the carapace deeply delineated, gastric, hepatic, branchial and cardiac regions tumid. Dorsal surface finely granulate, these granulations becoming coarser near the lateral margins and especially along the posterior margin where they form a submarginal row. There are four squamose tubercles forming a transverse row across the middle of the highest part of the mesogastric region; the distance between the inner pair is one and one-half times as long as that between the inner and outer tubercle. The rostrum is broad and short in the smaller adults; the interspace dividing the horns is small, shallow, triangular; the horns are broad, short, triangular, the apex being rounded and the outer margin sloping, more than twice as long as the inner margin; the rostral lobes are convex on the upper surface and separated by a median sulcus, a second slightly diagonal sulcus extends backwards from behind the outer antennal base between the rostral lobe and orbital border. In the larger adults (9 mm. greatest width) the rostral horns are not triangulate but are truncate, rounded, and the interspace is reduced, being more linear than triangular. There are three pairs of submedian tubercles

forming a longitudinal series, the first pair being adjacent to the rostral margin; the second pair about in line with the inner superior orbital angle, the third pair are about opposite the posterior orbital margin. The outer distal angle of the external basal antennal article is produced into a rugged triangulate process which is visible in a dorsal view as the inferior inner orbital angle, reaching nearly as far forward as the rostral horn. The superior orbital angle forms a raised, rounded tubercle stouter than and opposite to the second pair of rostral

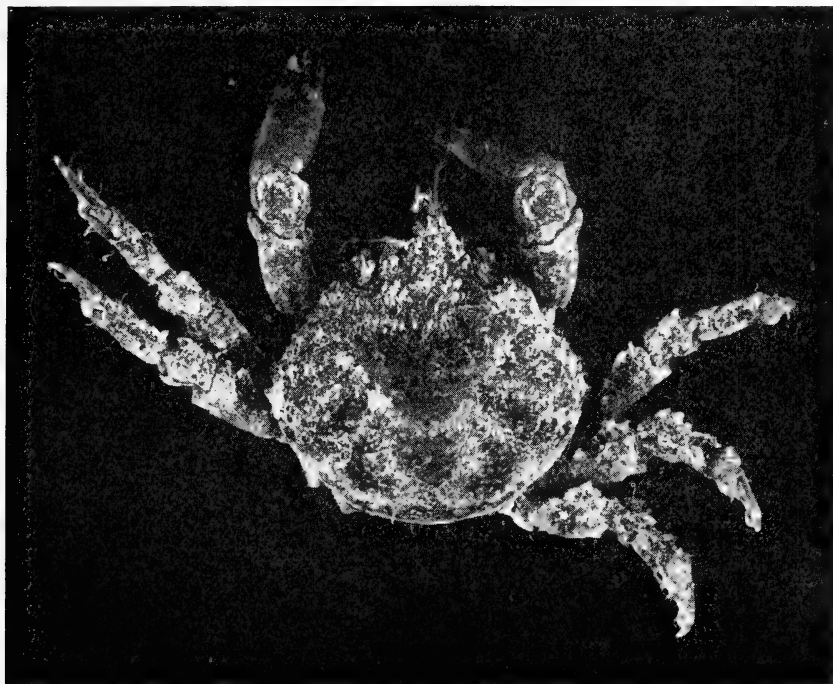


Fig. 52. *Teleophrys diana*,  $\times 2$ .

tubercles. In the younger adults there are two linear fissures in the superior orbital border; these are obsolete in the larger adults. The hepatic lobe is moderately tumid and bears a variable series of coarse granulations on its lateral margin, and a single larger squamose tubercle above these granulations, in line with the three lateral teeth of the margin of the branchial region. These latter have the anterior margin short, the apex sharp and strongly forward-directed and the postlateral margin convex and broadly rounded. The first and second teeth are almost subequal, the second tooth occasionally being a trifle larger than the first; the third or posterior tooth of the series is constantly the smallest. There is a large tubercle on the high posterior part of the branchial region, situated inward from and just posterior to the third branchial tubercle.

The eyestalk is stocky, slightly swollen, but constricted distally and produced on the upper dorsal surface into a rounded, tongue-like process that extends a little way onto the cornea but not to the distal region of the cornea. The cornea is subspherical, prominent; composed of many facets.

The external antennae have the basal article fused, large with the outer distal angle produced into a triangular tooth which is visible dorsally, appearing as the inferior orbital angle; there is a smaller sharp tubercle just below the external proximal angle of the basal antennal joint. The second (first free) joint of the external antennae is not quite half as wide as the distal end of the first joint, and arises from the inner distal angle of the basal joint; it is sub-cylindrical, dorso-ventrally compressed and furnished with a fringe of long curved setae along the distal half of the inner lateral margin; the third joint is slightly longer and narrower than the second; it is somewhat dilated distally and bears a cluster of setae nearly as long as the joint itself, on the inner distal angle; it also supports a flagellum composed of thirteen tapering articles each of which bears one or two long setae on its distal margin; the flagellum is about 2 mm. long, or one and one half times as long as the two free peduncular segments taken together.

The inner antennae are situated within the fossett beneath the rostral horns, into which they fold almost vertically; the basal joint is scarcely visible, the two free joints are stocky, cylindrical, subequal, about half as wide as long; the distal one bears on the ventral side of its distal end a minute flagellum composed of six small tapering articles, and a cluster of setae on each side of the flagellum; the larger stouter flagellum is adjacent and dorsal to the smaller one and about the same length. It consists of eight short tapering rings and bears a heavy, long brush of close-set setae which project considerably beyond the flagellum and cause it to appear much longer than it actually is.

The external maxillipeds have a small basal article; the exognath is about two times as long as wide and has its distal end triangulate, its apex reaching almost to the anterior border of the merus; it bears a very slender, multiarticulate palp which is as long as the exognath and finely setigerous. The ischium is two-thirds as broad as long, has the inner margin straight, finely setigerous, the inner half of the distal region produced in a rounded lobe; the merus arises from the outer half of the distal margin of the ischium; the merus is not quite as long on its inner lateral margin as it is wide, but is about as long on its outer lateral margin as it is wide and has the inner distal margin oblique and the external distal margin widened and rounded. The palp arises from a notch on the inner distal angle and consists of three articles which are subequal in length but the middle joint is less than half as wide as the proximal joint, and the distal joint is less than half as wide as the middle one; all three joints are heavily fringed with setae. There is a narrow space between the halves of the maxilliped, which is guarded by long fringes of setae.

The female abdomen is very broad and subcircular, covering the entire sternal region between the legs and reaching forward almost to the base of the external maxilliped. It consists of seven segments of which the first and second are subequal, forming the hinge and being narrower and shorter than the remaining segments. The third, fourth, fifth, sixth and seventh segments are

subequal in length but of varying width, forming the subcircular, broad pouch, the fifth segment being the widest. The second to fifth segments inclusive each bear paired appendages to which the eggs are attached. Each appendage consists of a long, curved, almost semicircular outer branch which is quite strong and fringed with fine close-set setae and lies subparallel to the outer margin of the pouch or when the pouch is filled with eggs, the outer branch of each of the four appendages spreads outside the margin of the pouch, somewhat like the sticks of a fan, forming a protective border. The inner branch of each appendage is very fragile; only about half as long, or less, than the outer branch and consists of two articles, the basal, which is almost two-thirds of the total length of the branch and the distal article, which is only one-half as long as the basal article and much frailer; the inner branch bears long silky setae to which the eggs are attached.

The male abdomen is also seven-segmented; it is triangular with the apex of the distal segment rounded. The first and second segments cover the sternal plate between the last pair of ambulatory legs. The first pair of male appendages are strong laminar processes which are flattened, having the outer third of the width of the process bent over upon the inner two-thirds, with a longitudinal hollow channel under this fold; the tip of the outer half is produced into a shape like that of a calla-lily blossom; the distal end of the inner third of the margin terminates somewhat below the outer angle and bears an oval membranous process which reaches almost as far as the outer process.

The chelipeds have the coxa small; the basis stout and produced to a tooth-like process on its posterior distal angle; the ischium is somewhat longer than the two preceding joints taken together and is produced on the anterior distal margin to a long triangulate process which extends nearly halfway the length of that margin of the merus; the merus is dilated distally and rounded on its upper surface which is ornamented with three subequally spaced longitudinal rows, composed of four or five tubercles each; the distal margin is produced into an enlarged node on the inner side and into a still larger toothlike node on the outer distal angle; the carpus is not quite one-half as long as the merus, is rounded on the upper side and has its edges cristate and four tubercles forming a diamond-shaped figure on the upper surface; the propodus is about a third longer than the merus and is half as high as it is long, with the upper edge carinate; a single low tubercle occurs near the middle of the proximal margin of the propodus. The propodal finger is about one-third of the entire length of the propodus and is spoon-shaped distally, crenulated around the distal margin and furnished with two tufts of setae inside the cutting edge. The hinged finger is similar to the propodal finger but is a trifle stronger and slightly curved downward distally with its crenulated margin meeting upon that of the propodus; there is a gap between the fingers which meet only at the tips. The hinged finger has a large rounded tooth on the cutting edge near the base.

The four pairs of cristate ambulatory legs are similar in structure but successively decrease in size posteriorly. The coxa and basis are small; the ischium is small and is produced on its anterior distal margin to a triangulate process; the merus is dilated distally and has its lateral and distal edges serrulate and a slightly less prominent longitudinal row of serrulations on the upper surface;



the carpus is about half as long as the merus, and is similarly cristate; the propodus is rather stocky, of about the same width throughout its length, with two rows of serrulations and with the posterior distal margin produced into a prominent rounded disc which interfits with a smaller, elongate rounded process which arises from the outer lateral surface of the dactyl, is directed backward and fits over the rounded projection of the propodus upon which it articulates. The propodal disc-like projection extends onto the dactyl for about one-third of its length. The dactyl is very strong and decidedly curved apically and armed with several rows of spinose setae, but devoid of serrulations.

*Eggs*.—The ovigerous females carry from about 150 to 200 eggs which are attached to the setae of the inner branches of the abdominal appendages. The eggs fill the brood pouch which becomes greatly distended, the outer branches of the pleopoda forming a side-wall between the margins of the abdominal belt and the sternal plastron. The eggs are spherical, golden yellow, their diameter being less than that of a medium-size sewing needle.

*Embryos*.—The largest embryos in the series at hand are about two and a half times as large as the diameter of the undeveloped eggs. They show huge elliptical black eye-spots whose long diameter appears to be about two-thirds of the height of the embryo and whose short diameter is about one-third of the width of the embryo.

*Young*.—Young adults of both sexes whose maximum diameter is scarcely 2 mm. show the specific characters unmistakably. The legs are cristate in miniature, and the minute granulations, visible only under high magnification, represent the tubercles of the dorsal surface of the carapace.

*Remarks*.—An adult male specimen whose maximum diameter is 6 mm. is a remarkably interesting example of the capacity for regeneration of lost appendages possessed by even the tiniest crabs. The present specimen has lost all four ambulatory legs on one side and the second and third ambulatory legs on the opposite side. Apparently all of these were lost at one time, for the six budded successors are in the same early stage of development, showing the same relative differences in size as do the full-grown legs.

*Teleophrys tumidus* (Cano)

*Mitraculus tumidus* Cano, Boll. Soc. Nat. Napoli, ser. 1, vol. 3, p. 186, pl. 7, fig. 7, 1889.

*Mithrax tumidus* Rathbun, Proc. U. S. Nat. Mus., vol. 38, p. 575, 1910.

*Teleophrys cristulipes* Rathbun, Proc. U. S. Nat. Mus., vol. 38, p. 536, (part; not pl. 46, fig. 2), 1910.

*Teleophrys tumidus* Rathbun, Bull. 129, U. S. Nat. Mus. p. 442, pl. 159, figs. 8 and 9, 1925.

*Diagnostic characters*.—Ambulatory legs with a lateral and a dorsal lobe on the posterior side of the propodus. Anterolateral spines one or two, branchial and marginal in position.

*Type*.—Cano's type came from Payta, Peru, and is deposited in the Naples Museum.

*Galapagos distribution*.—*Arcturus* station 54, Gardner Bay, off Hood Island, 15 feet; reef north of Tagus Cove, Tagus Hill, Albemarle Island.

*General distribution*.—Peru, Cocos Island and Galapagos Islands.

*Habits*.—This species dwells in the crevices of coral rock bottoms in the Galapagos.

*Material examined*.—Six from *Arcturus* station 54 Hood Island.

*Technical description*.—The front is subtriangulate, the rostral horns of moderate length, separated from each other by a very narrow sinus. The superior orbital margin has two weak emarginations. The outer margin of the basal article of the external antenna is not dentate, but forms a very faint lobe posteriorly; the second free article is short and stout, being more than one-half as wide as long. The antennules are well-developed and fold within the septum.

The external maxillipeds have the ischium subrectangular, with the inner distal angle roundly produced; the merus is more than one-half as long as the ischium and has the inner distal angle deeply notched for the reception of the three-jointed palp.

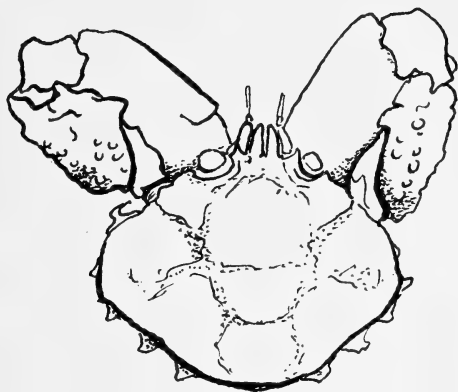


Fig. 53. *Teleophrys tumidus*,  $\times 1\frac{1}{2}$  (After Rathbun).

Carapace longer and more triangular than *Teleophrys diana* or *T. cristulipes*; dorsal surface with granulations abundant but not forming a definite pattern as in *diana*; with fewer tubercles and spines than in *cristulipes*. Branchial region unusually elevated on either side of the cardiac region. Anterolateral margin with an hepatic tubercle, followed by a branchial tubercle, which is succeeded by a branchial spine placed just in advance of the second spine which is situated at the lateral angle and is followed by a tubercle and the postlateral spine.

The chelipeds are less rugose than those of *cristulipes* but more so than those of *diana*. There is a tubercle near the middle of the margin of the palm. The fingers are rather stout and tapering.

The ambulatories are very stout, especially the propodus which has a lateral as well as a dorsal lobe; the dactyl is short, stout and distinctly curved.

Genus: *Stenocionops* (Leach, Mss.) Desmarest, 1823

*Stenocionops ovata* (Bell).

*Pericera ovata* Bell, Proc. Zool. Soc. London, vol. 3, p. 173, 1835 (1836);  
Trans. Zool. Soc. London, vol. 2, p. 60, pl. 12, figs. 5, 5  $\sigma$ , 5  $\phi$ , 1836.

*Stenocionops ovata* Rathbun, Proc. U. S. Nat. Mus. vol. 38, p. 574, 1910; Bull. 129, U. S. Nat. Mus. p. 459, pl. 264, figs. 5-7, (after Bell), 1925.

*Diagnostic characters*.—Rostral horns divergent; carapace elongate-oval with eight median spines, and four or five lateral marginal spines.

*Type*.—Mr. Bell's type, which is believed to be no longer extant, was collected in the Galapagos Islands, in six fathoms.

*Galapagos distribution*.—Galapagos (type locality).

*General distribution*.—Known only from the type locality.

*Material examined*.—None.

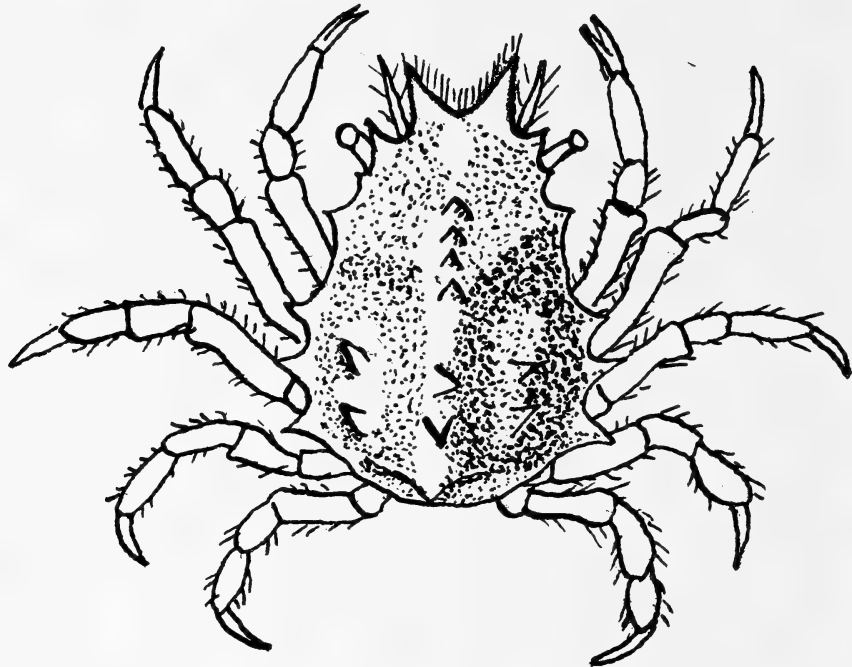


Fig. 54. *Stenocionops ovata*,  $\times 2$  (After Bell).

*Technical description*.—"The carapace of this species is oval, longer in proportion to its breadth than many others, considerably elevated, at least in the female, the only six as yet observed, sparingly covered with short close hair, and furnished with numerous spines of various length and size, of which there are four small ones on the median line of the gastric region, three on the cardiac and genital, of which the middle one is the largest, one on the intestinal, a very small one on each hepatic, three on the branchial, and four or five on each lateral margin. The orbit is formed nearly as in the other species, the upper and anterior spine extending much beyond that of the basal joint of the external *antennae*, is very broad; its outer spine is short and triangular, and there is a very small tooth beneath the insertion of the second joint. The moveable portion is as long as the rostrum, and beset with a double series

of bristles. The second joint of the internal footstalk of the outer pedipalps is triangular, the anterior margin rounded and scarcely notched.

The abdomen of the female is oval, seven-jointed, and has an obtuse interrupted *carina* running its whole length, formed by a tubercle on the center of each joint; the first joint has a small tooth.

The legs are without spines, but covered with close hair; the first pair in the female is not larger than the others, and shorter than the second and third, which are the longest of the whole. The hand is simple, naked and slender; the claw small and furnished with extremely minute teeth.

The colour is a rich rather light reddish brown.

Length 1 inch, breadth six lines.

Two specimens, both females, were dredged by Mr. Cuming at the Galapagos Islands on coral sand at the depth of six fathoms." (*After Bell*.)

#### Genus *Microphrys* Milne Edwards, 1851

*Microphrys aculeatus* (Bell).

*Pisa aculeata* Bell, *Proc. Zool. Soc. London*, vol. 3, 1835 (1836), p. 171;

*Trans. Zool. Soc. London*, vol. 2, p. 50, pl. 9, fig. 7, 1836.

*Milnia aculeata* Stimpson, *Ann. Lyc. Nat. Hist. New York*, vol. 7, p. 52, 1860.

*Microphrys aculeatus* A. Milne Edwards, *Crust. Rég. Mex.*, p. 63, 1875;

Rathbun, *Proc. U. S. Nat. Mus.*, vol. 38, pp. 546 and 574, pl. 45, fig. 4, 1910; *Bull. 129, U. S. Nat. Mus.*, p. 500, pl. 271, fig. 1, 1925.

*Microphrys platysoma* Rathbun, *Proc. Wash. Acad. Sci.*, vol. 4, p. 285, 1902; *Proc. U. S. Nat. Mus.*, vol. 38, pp. 535 and 574, 1910.

*Diagnostic characters*.—Two prominent raised disks on the anterolateral wall. There is no tooth or lobe behind the anterolateral spine of the basal antennal segment. There are four spines on each branchial region, two of which are marginal. Five tubercles form an arc across the gastric region.

*Type*.—Bell's type, which came from the Galapagos Islands, is believed to be no longer extant.

*Galapagos distribution*.—Bell's type locality is given as "Galapagos Islands"; this species has also been taken on the reef north of Tagus Hill, Tagus Cove, Albemarle Island, by the Hopkins-Stanford Expedition and taken off Hood Island, depth 15 feet, *Arcturus* station 54, by William Beebe.

*General distribution*.—Galapagos Islands, Ecuador and Peru.

*Material examined*.—Two female specimens and one young specimen from off Hood Island, station 54, collected by William Beebe while diving in 15 feet of water.

*Technical description*.—The carapace, which is broadly pyriform, measures 8 mm. long from base of rostrum to posterior margin, 7 mm. greatest width, and is very well furnished with clusters of very high fish-hook-shaped setae many of which have tubercles or granules at their base; there are many small hairs between these hooks; the surface of the carapace is pitted. The paired rostral horns are long, acuminate, separated by a deep V-shaped sinus which is three-fourths as wide distally as the horns are long. The slender anterolateral spine of the basal antennal segment is directed outward and is two-thirds as long as the rostral spine. The superior orbital border is marked by closed fissures; the postorbital cup is flat, disk-like; there are two large, prominent, oval disks, situated on the anterolateral wall, one being hepatic and one bran-

chial in position. Five tubercles form an arc across the summit of the gastric region; two tubercles, one behind the other, on the gastric region are placed posterior to the median one of the five tubercles forming the arc. There are two tubercles near the outer edge of each branchial region. There are normally four spines on each branchial region, three of which form a transverse row on the cardiac region; the outer spine of this series is marginal, the fourth spine is lower and more anterior than the third and is also marginal. There is said to

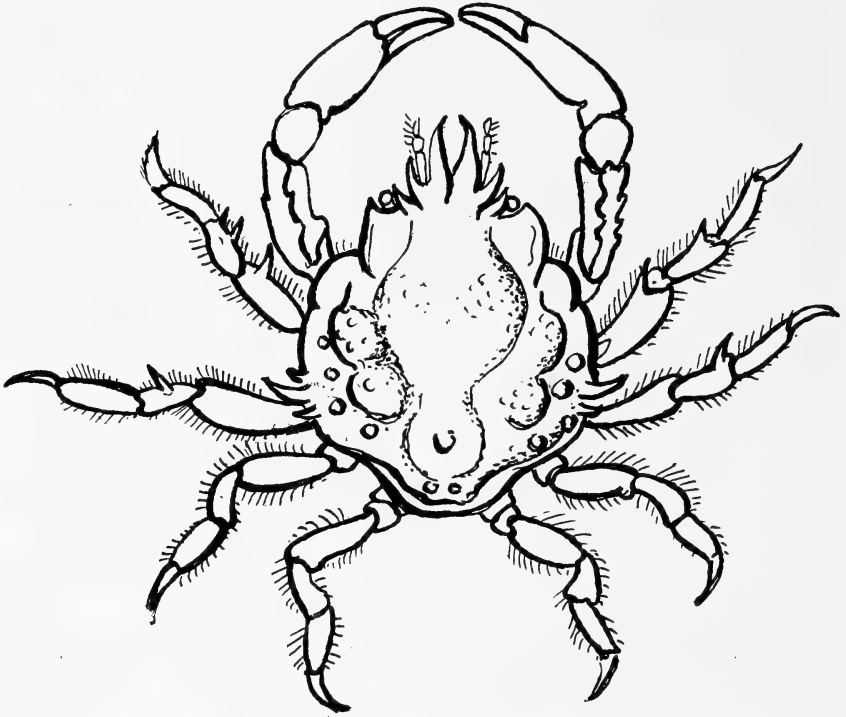


Fig. 55. *Microphrys aculeatus*,  $\times$  about 2 (After Bell).

be an occasional variation in this row of spines, the innermost one sometimes being reduced or absent; sometimes a secondary spine occurs between the second and third branchial spines. There is a row of twelve prominent tubercles forming an arc just above the posterior margin. Each tubercle bears a tuft of long curled hairs; there is a row of similar hairs along the anterolateral regions; and another on the gastric region running forward almost to the tips of the rostral horns.

The female abdomen is seven-segmented and is quite narrow.

The antennulae are small, placed beneath the rostral hood and fold diagonally within the M-shaped fossett

The external antennae have the basal joint greatly dilated and armed at

the outer distal angle with a long slender spine, which is visible dorsally; the free second and third joints are long and slender, and lie beside the rostral spine, the two together almost reaching the apex of the spine; the flagellum is long and slender, consisting of seven or eight long rings and reaching beyond the tips of the extended cheliped.

The external maxillipeds are rectangular; the long second joint of the exognath is convex on its inner lateral margin and is two-thirds as wide as the ischium; the ischium is cleaver-shaped with the inner distal angle produced; the merus is a little more than half as long as the ischium, with the distal margin truncated, the external distal angle produced and rounded, and the inner distal angle emarginate for the reception of the three-jointed palp; the basal joint of the palp is quite robust, the second and third joints are small and tapering.

The chelipeds (female) are equal and are only slightly larger than the first pair of ambulatories. The merus of the chelipeds is elongate, compressed, and has three triangulate teeth above; the carpus is rounded and nodulose; the palm is moderately enlarged and compressed; the fingers are slender, compressed, curved, hollowed at the tip and shallowly dentate.

The four pairs of ambulatory legs successively diminish in size posteriorly. The most anterior leg has a long sharp spine on the carpus and another subdistal spine on the merus. The next (second) leg has a spine on the carpus only. The dactyli are well developed, curved and sharp-pointed.

*Microphrys triangulatus* (Lockington).

*Mithraculus triangulatus* Lockington, *Proc. California Acad. Soc.*, vol. 7, p. 73, 1876 (1877).

*Mithrax triangulatus* Rathbun, *Proc. U. S. Nat. Mus.*, vol. 21, p. 578, 1898.

*Microphrys branchialis* Rathbun, *Proc. Washington Acad. Sci.*, vol. 4, p. 285, 1902.

*Microphrys triangulatus* (Rathbun), *Bull.* 129, *U. S. Nat. Mus.*, p. 504, pl. 177, 1925.

*Diagnostic characters*.—Carapace short and broad, nodulose, nodules almost smooth. Three marginal teeth or lobes on basal segment of antenna. Chelipeds of male very long and strong, palms high.

*Type*.—Gulf of California (type-locality); the type is not extant.

*Galapagos distribution*.—Galapagos Islands.

*General distribution*.—Lower part of Gulf of California; Galapagos Islands. Shallow water to 10 fathoms.

*Material examined*.—None.

*Technical description*.—The following is Miss Rathbun's description: "Carapace a little longer than broad, thick and nodulose, the nodules ornamented sparingly with low granules, so as to appear almost smooth. The largest nodule is the anterior branchial, which is oblique, elongate and overhangs the lateral wall of the carapace. Behind and below this lobe there is a short blunt spine or lobe at the lateral angle of the carapace. The most prominent granules are on the anterior portion of the carapace, namely, two on the summit of each protogastric lobe, a row of three on each epigastric lobe, one or two at base of each preorbital tooth. Two large tubercles on intestinal region, from each of which a submarginal line of granules extends outward.

Rostrum short, deeply divided; horns broad, inner margin straight, outer

margin convex, sinus narrow. Preorbital lobe little advanced, blunt, granulate; postorbital cup also little advanced. Basal antennal segment broad, bearing two broad blunt lobes on the margin, each lobe outwardly arcuate, also a small subacute tooth at the base of the next or movable segment, and a tubercle on the ventral surface near the postero-external angle.

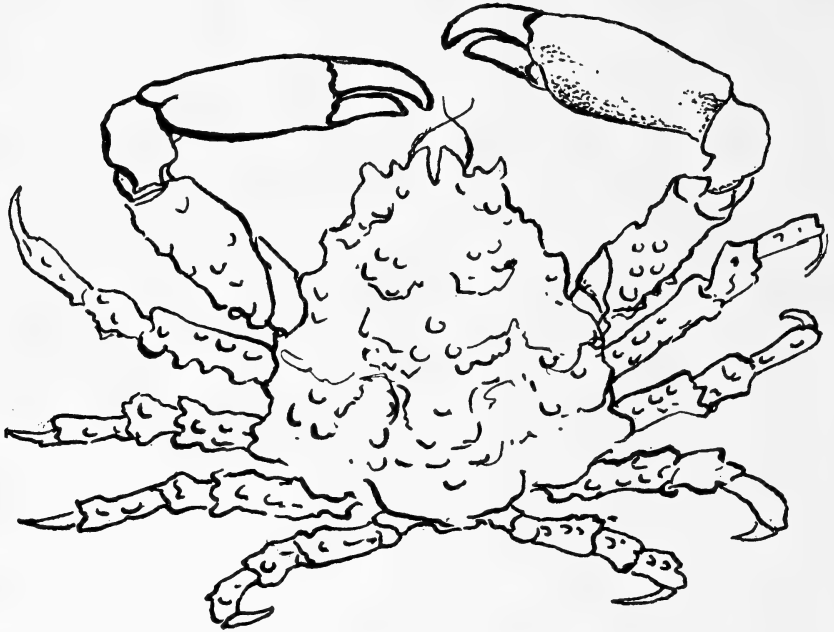


Fig. 56. *Microphrys triangulatus*,  $\times 3$  (After Rathbun).

Chelipeds of male very strong, one and two-thirds times as long as carapace. Arm tuberculate on upper margin and inner and outer surfaces; wrist nearly smooth; palm unusually high, its upper length about one and two-thirds times its height; immovable finger a little convex below, a large tooth on the dactyl a little behind middle of gape. Merus joints of legs with about two rows of large tubercles some of which are conical and subacute; a few of the same are on the carpus, from one to three of these being enlarged; two tubercles on each propodus.

*Color*.—In spirits, uniform reddish (Lockington).

**Family: PARTHENOPIDAE**

**Subfamily: PARTHENOPINAE**

**Genus Parthenope Weber, 1795**

*Parthenope* (*Platylambrus*) *exilipes* (Rathbun).

*Lambrus* (*Parthenolambrus*) *exilipes* Rathbun, *Proc. U. S. Nat. Mus.*, vol. 16, p. 234, 1893.

*Lambrus hassleri* Faxon, *Bull. Mus. Comp. Zool.*, vol. 24, p. 152, 1893.

*Parthenope (Platylambrus) exilipes* Rathbun, *Bull. 129, U. S. Nat. Mus.*, p. 523, pls. 184 and 185; pl. 277, figs. 1 and 2, 1925.

*Type*.—The type, a male specimen, was collected off San Domingo Point, Lower California, Mexico, and is deposited in the United States National Museum.

*Galapagos distribution*.—Off Charles Island, 78.5 fathoms, one female specimen.

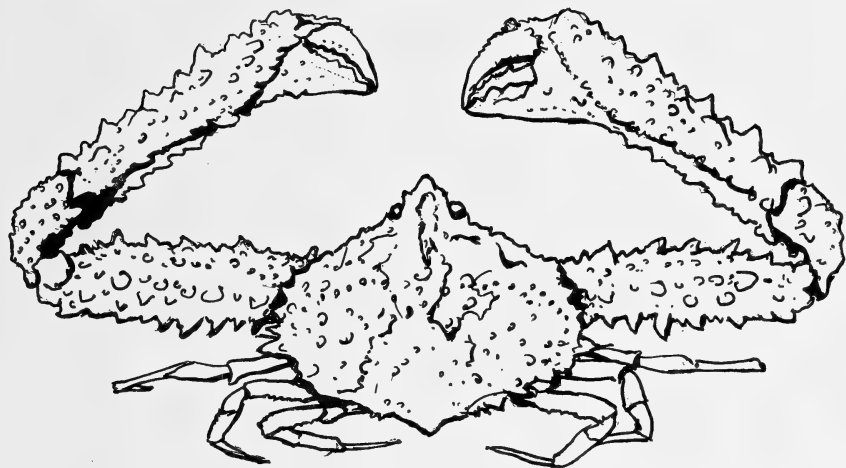


Fig. 57. *Parthenope (Platylambrus) exilipes*, natural size.

*General distribution*.—West coast of Mexico; Panama Bay; off Cocos Island; Galapagos Islands. From depths ranging from 31 to 80 fathoms.

*Material examined*.—None.

*Technical description*.—The following is Dr. Rathbun's diagnosis: "Near *pourtalesii*; carapace broader; branchial regions more expanded and inflated, the inflation extending farther in toward the cardiac area so as to involve the oblique row of small tubercles, which in *pourtalesii* lies low in the fossa between branchial and cardiac regions; inter-regional depressions shallower; branchial pits deeper; a transversely-oblique line of tubercles across anterior branchial region more conspicuous, spines and teeth of carapace and chelipeds shorter and stouter, those on chelipeds not lacinated to such a degree; anterior margin of carpus and propodus of all the legs finely spinulose or denticulate.

*Measurements*.—Female (21966) length of carapace 29.7, width of same 40.3, length of cheliped 76.4 mm."

#### Subgenus *Pseudolambrus* Paulson, 1875

*Parthenope (Pseudolambrus) excavata* (Stimpson) (Hexagonal Crab).

*Lambrus excavatus* Stimpson, *Ann. Lyc. Nat. Hist. New York*, vol. 10, p. 98, 1871; A. Milne Edwards, *Crust. Rég. Mex.*, p. 154, 1878.

*Parthenope (Pseudolambrus) excavata* Rathbun, *Bull. 129, U. S. Nat. Mus.*, p. 529, pl. 189, 1925.



*Diagnostic characters.*—Carapace triangulate with five deep depressions on the anterior half of body. Anterolateral margins angulate. "Chelipeds deeply concave above, the concavity defined by prominent dentate crests" (Stimpson).

*Type.*—Professor Stimpson's type material consisted of two specimens collected at Manzanillo, Mexico, by John Xantus. They were lost in the great Chicago fire.

*Galapagos distribution.*—Off Hood Island, *Arcturus* station 54, in 15 feet of water.



Fig. 58. *Parthenope (Pseudolambrus) excavata*,  $\times 3$ .

*General distribution.*—In addition to the type-locality, Manzanillo, Mexico, I find only one specimen from Panama, collected by Captain John M. Dow, recorded. The *Arcturus* Expedition has extended the known range of this species to the Galapagos Islands.

*Material examined.*—One female specimen was taken at Station 54, Hood Island, Galapagos Islands, by William Beebe, while diving in fifteen feet of water. This is the first record of this species from the Galapagos Islands.

*Habits.*—Little is known of the habits of this rare crab. It was found in the crevice of the coral rock, which it so much resembles in the sculpturing of its carapace. The eroded and nodulose surface of the carapace of the Galapagos specimen is rendered even more inconspicuous by the patch-like colonies of two

species of Bryozoa, two kinds of algae, one species of tube-dwelling worm, and one species of sponge which adhere to it.

*Technical description.*—Carapace 27 mm. greatest width; 18 mm. long; irregularly hexagonal, its greatest width being through the posterior region. The rostrum is prominent, though sharply deflexed, triangulate, with the margin irregularly, vaguely dentate. The anterolateral margins are concave, forming an angle with the outer lateral margin, and terminate posteriorly in a decided projecting angle; the posterolateral are but little concave forming a decidedly obtuse angle with each other, because of the little projection of the intestinal region. The posterior margin is narrow. The margins are cut into small teeth which are short, triangular and more regular on the anterior and outer lateral margins, being prominent at the lateral angle; on the postlateral margins these teeth are less triangulate and more irregular. There is a deep concavity on the frontal region which extends backwards a little ways. In addition to the normal delineation of the branchial and cardiac regions there are four deep cavities or depressions in front of the branchial region; two of these separate the branchial and hepatic regions and the other two separate the branchial from the gastric regions. The dorsal surface of the carapace is rough; the raised areas are covered with well developed low granules or tubercles. Three flat triangular denticles form a row on the ventral surface behind the cheliped.

The female abdomen is seven-segmented, oval, of moderate width and with the distal segment broadly rounded; the lateral margins are densely fringed with short plumose setae. The external surface of the abdomen is very rugose, the middle of each segment being occupied by a ridge-like, setose tubercle which is as long as the segment; several smaller tubercles are placed on each side of the central one, the second to fifth segments inclusive respectively bear the paired biramose appendages. Each appendage consists of a short basal joint and two, long, curved, subequal branches, each of which is heavily fringed with exceedingly long plumose setae.

The male abdomen has not been described.

The eyestalks are very convex and are covered with a calcareous granulose substance similar to the carapace. The cornea is terminal, subspherical, shining black, composed of numerous hexagonal facets.

The inner antennae have an enormous basal joint which is very rough on its outer surface; the first free joint is long, moderately slender and granulose externally, the next joint is slightly shorter and is cylindrical and bears distally the two small flagella.

The external antennae are small; the distal inner angle of the basal joint does not reach the front; the outer distal angle reaches as far as the inner inferior orbital angle; the second antennal joint is small and is in the orbital hiatus; the third joint is scarcely larger than the flagellum, which consists of nine, short, slender, tapering articles.

The external maxillipeds fit closely in the buccal cavity; the exognath is long, tapering, thin on the inner distal margin and bearing a very slender palp; its outer surface bears a row of three or four granules. The ischium is subrectangular with its inner distal margin slightly produced; its outer surface granulose and channelled by a median longitudinal sulcus; its inner edges are crenulate

and furry with very short setae. The merus is as wide as long, and is about one-half as long as the ischium, with its outer distal lobe rounded and its inner distal lobe deeply incised for the reception of the three-jointed palp. The first joint of the palp is large and completes the outline of the merus, the second and third joints are cylindrical, tapering, fringed with long setae; they are bent downward and lie between the meral joints.

The chelipeds in the present specimen have been broken off and the regeneration of these appendages has begun. These folded, budded chelae do not quite reach to the margin of the carapace but the diagnostic features cited by Stimpson may be clearly discerned.

The following is Professor Stimpson's description of the chelipeds:

"The chelipeds are much shorter and stouter than in the typical forms of the genus, and are deeply concave above, the concavity being smooth or nearly so, and defined by prominent marginal crests, which, except on the carpus, are strongly toothed. The meros joint of the cheliped is particularly short; its anterior crest is armed with three or four teeth, and its superior one with only two large teeth, the outer one of which is much the largest. In the hand the crest of the superior margin is armed with six unequal, approximated, triangular teeth; and that of the outer margin with two conical distant teeth, besides the knob at each extremity. The lower surface of the hand is ornamented with four or five rows of granulated tubercles, those of the middle row being largest and most conspicuous; inner margin serrated with granulated teeth.

Length of the carapax in a female, 1.20; breadth, 1.38 inch; proportion 1 : 1.15; length of meros-joint of cheliped, 0.68; length of greater hand, 1.20 inch.

It is distinct from all other known species with the carapace broader than long, in the shortness of its chelipeds. In one of the specimens before me the right hand is nearly twice as broad as the left."

The four pairs of ambulatory feet of the specimen secured by Mr. Beebe are of similar shape but successively decrease in size posteriorly. The first and second pairs are almost equal, the third pair only reaches to the base of the dactyl of the second pair and the fourth pair is conspicuously smaller reaching only to the distal end of the propodus of the third pair. All of the legs are decidedly compressed, crested above, the margins are dentate and the outer surfaces of the legs are granulose. The three proximal joints are small; the meral joint is the longest joint of the appendage, and is three-sided, the ventral face being narrow, excavate between the carina-like margins, the upper portion is very compressed and its margin crested and dentate; the carpus is about half as long as the merus; the propodus is a little longer than the carpus and has one or two angulations on its ventral margin made by large granules; the dactyl is as long or a trifle longer than the propodus and is stout, sub-cylindrical, tipped with a strong spine and covered with granules and short furry setae.

## Superfamily: BRACHYRHYNCHA

## Family: PORTUNIDAE

## Subfamily: PORTUNINAE

Genus *Portunus* Weber, 1795Subgenus *Achelous* DeHaanKey to the Galapagos species of the subgenus *Achelous*.

Arm and hand very short; carpal spine unusually long, reaching halfway to the upper marginal propodal spine when the hand is flexed.

*brevimanus*

Lateral teeth alternately large and small; lateral spine only slightly longer than seventh tooth; one small spine on posterior distal angle of merus of swimming feet.

*angustus*

Carapace with frontal border unusually prominent; ridges and rugosities of carapace decidedly pronounced. One strong spine on merus of swimming feet.

*stanfordi**Portunus (Achelous) brevimanus* (Faxon).

Under *Achelous spinimanus* Faxon, *Mem. Mus. Comp. Zool.*, vol. 18, p. 23, 1895 (not *Portunus spinimanus* Latreille) is described *Achelous brevimanus* Faxon (in text).

*Portunus (Achelous) brevimanus* Rathbun, *Proc. U. S. Nat. Mus.*, vol. 21, p. 593, 1899; *Proc. U. S. Nat. Mus.*, vol. 38, p. 578, 1910.

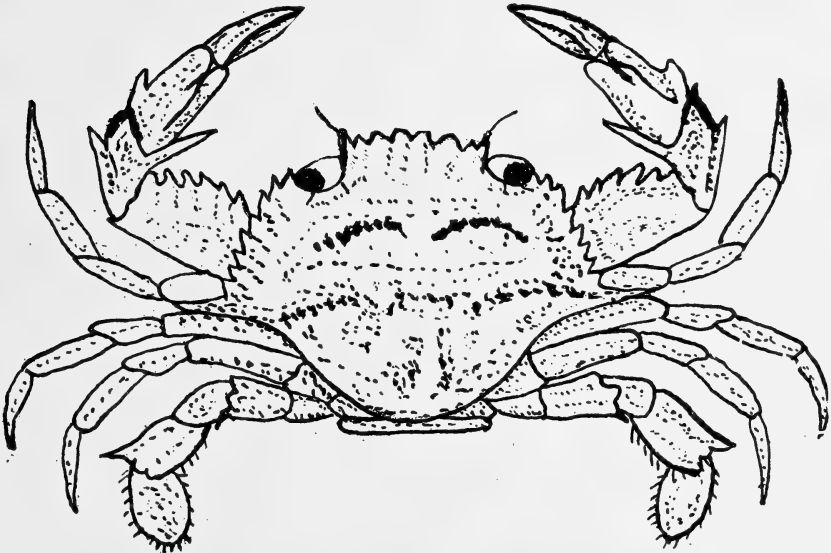


Fig. 59. *Portunus (Achelous) spinimanus*, natural size.

*Diagnostic characters.*—Arm and hand shorter than in related species; a longer spine on the inner side of the carpus.

*Type*.—Two male specimens from off Cocos Island, *Albatross* station 3368, furnished the material upon which this species is founded; they are deposited in the Museum of Comparative Zoology, Cambridge, Mass.

*Galapagos distribution*.—Off Hood Island 20 and 40 fathoms, Albemarle Island.

*General distribution*.—Pacific, off Cocos Island; Galapagos Islands.

*Material examined*.—One broken.

*Technical description*.—The following is Dr. Faxon's description of the species: "These specimens differ from the typical form in having a shorter arm and hand, a longer spine on the inner side of the carpus; in having a short spine at the distal end of the superior border of the propodus and two small spines at the distal end of the merus of the last pair of legs. Of these two spines the larger is on the posterior lateral angle of the segment, the smaller one just above it. The carpal spine reaches halfway to the extremity of the spine on the upper margin of the propodus when the hand is flexed. The length of the carapace is 44.5 mm.; breadth, 69.5 mm.; length of merus, 33 mm.; length of chela, 47 mm.; breadth, 15 mm.; length of dactylus 25 mm.; length of carpal spine, measured from the anterior border of the carpus, 10.5 mm.

If these differences prove to be constant in specimens from this region the form may be called *Achelous brevimanus*."

*Portunus (Achelous) stanfordi* Rathbun.

*Portunus (Achelous) stanfordi* Rathbun, *Proc. Washington Acad. Sci.*, vol. 4, p. 282, pl. 12, fig. 11, 1902; *Proc. U. S. Nat. Mus.*, vol. 38, p. 578, 1910.

This species was apparently named in honour of the Hopkins-Stanford Galapagos Expedition, by which it was discovered.

*Diagnostic characters*.—One prominent spine on the merus of the fifth legs. Carapace with the frontal border more prominent and the ridges and rugosities more pronounced than are those of the closely related species *Portunus minimus*.

*Type*.—The type material consisted of two males and three young specimens taken on the reef north of Tagus Hill, Tagus Cove, Albemarle Island, Galapagos, by the Hopkins-Stanford Expedition, and deposited in the United States National Museum.

*Galapagos distribution*.—Tagus Cove, Albemarle Island (type-locality); off Hood Island, *Arcturus* station 54, depth 15 feet.

*General distribution*.—This species is known only from the Galapagos Islands.

*Technical description*.—Carapace 13.5 mm. long; 22.5 mm. wide from tip to tip of lateral spine; interorbital space 7 mm. wide. The carapace is covered with very fine hairs; along the margins these hairs are longer and are plumose. Beneath the hairs the carapace is covered with rounded granules, which form rows of beading along the margins of the spines. The ridges and rugosities of the carapace are very pronounced; two, one behind the other, traverse the mesogastric region; the cardiac region is strongly delineated and unusually high, appearing as two lobes, forming a heart-shaped protuberance; the inner area of the branchial region is emphasized by two rounded tubercles, the anterior of which is contiguous with a prominent ridge that curves out toward the lateral

border and forms a slender beaded median rib on the lateral spine. Behind the second tubercle there is a short prominent ridge. The interorbital border is prominent and is divided into eight teeth; the inner four are subequal, triangular; the inner pair a little longer and are slightly narrower at the base than the outer and are separated from each other by a V-shaped sinus and from the outer pair by a U-shaped sinus; the outer four teeth are quite small, blunt, two situated above each antenna, separated from each other by a shallow concavity and from the inner four by shallow V-shaped sinus. The superior orbital margin

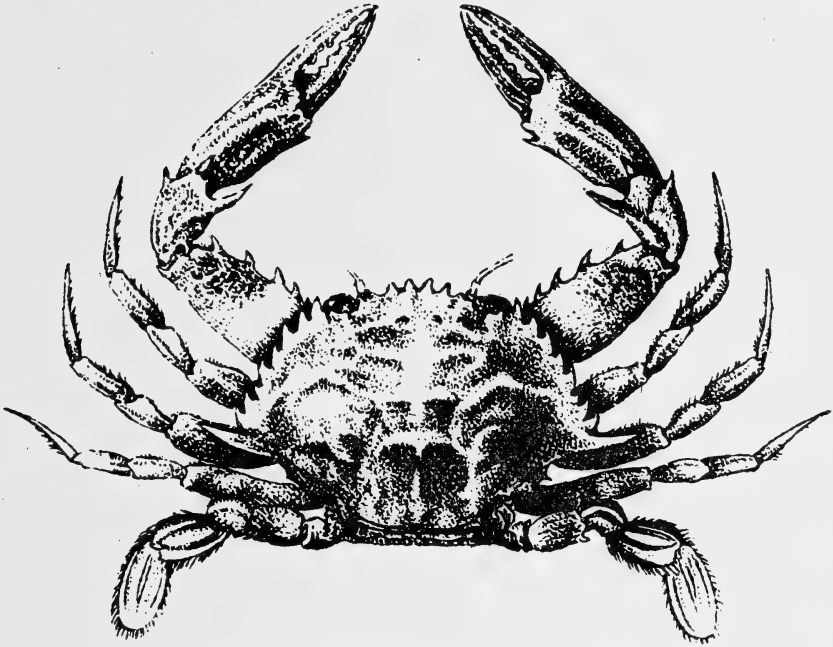


Fig. 60. *Portunus (Achelous) stanfordi*,  $\times 1\frac{1}{4}$  (After Rathbun).

is finely granulate, fringed with plumose setae and broken by two fissures, the inner of which is linear, the outer is V-shaped and has its inner angle produced.

The inner suborbital tooth is very prominent and is produced as far as the median pair of frontal teeth. The outer sinus is small, V-shaped. The postorbital tooth is well developed and is equal to the teeth of the anterolateral margin of which there are seven in addition to the postorbital; all are decidedly forward-directed and have the short anterior margin coarsely beaded, and the long, convex outer margin finely granulose; the first and second teeth are subacute, the remaining six are acute. The second, fourth and sixth teeth are smaller than the others, and decrease in the sequence named; the fifth tooth is the widest of the series. The ninth or lateral spine is about two and three-fifths as long as the eighth spine and is very acuminate, ribbed by a beadlike ridge and directed outward and upward. The posterior margin is carina-like.

The male abdomen is triangulate, five-segmented, the third segment being composed of three fused segments. The first pair of male appendages are paired, slender, tapering rods.

The female abdomen is broadly subtriangulate with the lateral margins of each segment forming a separate curve; it is six-segmented; the terminal segment is much smaller than any of the preceding segments. The four pairs of biramose appendages are long and heavily fringed. Each appendage consists of a short basal joint, a two-jointed inner branch and a slightly longer outer branch.

The eyestalk is short, constricted below the cornea and produced into a narrow tongue-like projection on the outer (frontal) side. The cornea is sub-spherical and is composed of very many small, hexagonal facets.

The inner antennae are well-developed; the basal article is short; the second article is elongate cylindrical; the third article is similar to the second but slightly shorter and more dilated distally; the smaller flagellum consists of six moderately developed articles; the larger flagellum consists of a stout basal and thirteen short stout, tapering rings, and bears a dense brush of long plumose setae on its under side.

The external antennae has the basal joint situated in the orbital hiatus and produced into a prominent node-like process on its outer distal joint; the second joint is long and slender; the third joint is only about two-thirds the size of the second joint; the flagellum consists of thirteen tapering articles and reaches to midway the posterior margin of the postorbital tooth.

The external maxilliped is very setigerous both on its outer surface and its inner margin. The two halves are separated from each other by a moderate space. The basal joint is short; the second joint of the exognath is about one-third as wide as long, and reaches to the outer distal angle of the merus; it bears a very slender multiarticulate palp which is nearly as long as the joint supporting it. The ischium is subrectangular, about twice as long as wide, traversed by a longitudinal sulcus; the merus is about four-fifths as long as the ischium and has its inner and distal margins roundly produced; the inner distal angle is slightly excavate for the reception of the rather stout, three-jointed palp.

The chelipeds are equal in both sexes. The three proximal joints are small but strongly developed; the merus is approximately as long as half the width of the carapace and furnished with five acute spines along the anterior margin; the proximal two of which are weaker. The upper posterior margin of the merus is rough with denticle-like granulations and there is a larger, sharp spine at the outer distal angle; the carpus is convex on its outer surface and traversed by two curved lines of beading; the outer distal angle is produced into an acute spine and the inner distal angle is produced into a very long sharp spine which is about three and a half times as long as the one on the outer angle. The propodus is about one-third longer than the merus, the fingers comprising almost one-half of this length; the palm is carinated on both its upper and lower margins; the upper carina terminating distally in an acute spine. Two more longitudinal carinae composed of denticle-like tubercles traverse the outer surface of the palm, the areas between, above and below the carinae being somewhat concave and finely setigerous. There is another acute spine on the

upper, outer proximal part of the palm, adjacent to the distal angle of the carpus. The fingers are subequal, long and slender, with the tips curved and crossing. The cutting edges are serrated with alternately large and small teeth, which fit closely upon each other; the upper finger bears a greatly enlarged, blunt basal tooth. Both fingers are fluted on the outer surface by carinae.

The first, second and third ambulatory legs are similar, slender, with long, acuminate, fluted dactyli, and decrease in length in the order named. The fifth pair of legs have a prominent spine on the posterior subdistal margin of the merus, and have the propodus and dactyl flattened into oval swimming paddles which have fringed setae.

*Portunus (Achelous) angustus* Rathbun.

*Portunus (Achelous) angustus*, Rathbun, *Proc. Nat. Mus.*, vol 21, p. 594, pl. 44, fig. 2, 1899; *Proc. Washington, Acad. Sci.*, vol. IV, p. 287, 1902; *Proc. U. S. Nat. Mus.*, vol. 38, p. 578, 1910.

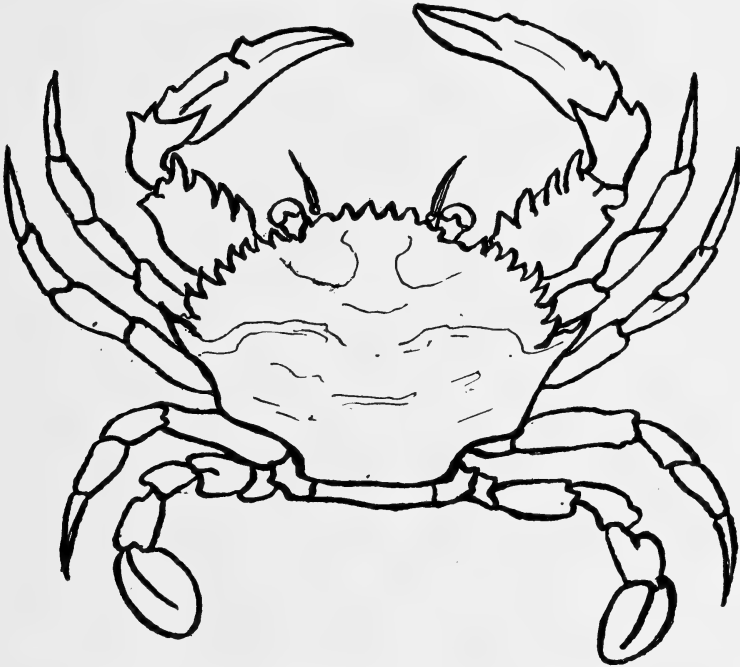


Fig. 61. *Portunus (Achelous) angustus*,  $\times 1\frac{1}{2}$  (After Rathbun).

*Diagnostic characters*.—Front advanced, 8-toothed; lateral teeth alternately large and small; lateral spine only slightly longer than seventh tooth; a spine at posterior distal angle of merus of swimming feet.

*Type*.—One female taken off Hood Island, Galapagos, 20 fathoms, *Albatross* station 2812, which is deposited in the United States National Museum.

*Galapagos distribution*.—One female taken off Hood Island, Galapagos, *Albatross* station 2812.



*General distribution.*—One female taken off Hood Island, Galapagos.

*Material examined.*—None.

*Color.*—"Although this crab has been for a long time in alcohol, it seems to be of a reddish hue. The basal half of the fingers is red, the next quarter is white, the remainder is brown, except the tips, which are white." (Rathbun.)

*Technical description.*—(After Rathbun): "Carapace narrow, pubescent except upon the transverse granulated lines; in shape resembling *Portunus ordwayi* (Stimpson). Front advanced; four middle teeth subacute, the outer pair broader at base than the inner, and separated from the inner pair by wider sinuses than the median sinus, and from the supra-antennal angle by a deep V-shaped sinus. Supra-antennal lobe bidentate; teeth acute. Antero-lateral teeth alternately large and small, the last tooth or lateral spine very little longer than the seventh. The inner suborbital tooth is acute and equally advanced with the second pair (reckoning from the middle) of frontal teeth; there are no teeth on either side of the outer orbital fissure.

The merus of the cheliped of the type specimen, a female, has four spines on its inner margin, graduated from a large one near the distal end to a small one near the ischium; a very small spine on the outer margin at the distal end. Carpus with a small external distal spine and a long inner spine reaching, when the arm is flexed, to the spine next to the smallest on the merus. The hand has two large spines, one next the carpus and one on the superior margin at one-third its length from the dactylus. The ridges on the carpus, propodus, and dactylus are very coarsely granulated with acorn-shaped granules. The depressions are pubescent. The extero-superior surface of the merus is crossed by a longitudinal ridge. The inferior margin of the merus of the left natatory foot is armed with a sharp spine near the distal end; on the right foot there are two smaller spines in the same position.

This species has considerable resemblance to *Charybdella* (= *Cronius*), but the basal antennal joint is not so strongly produced as in that genus. It can also be told by its narrower carapace and frontal teeth, and few spines on the hand.

*Dimensions.*—Female: Total length of carapace, 25.5 mm.; total width 37.2 mm.; width between the last sinuses, 33.5 mm.; exorbital width, 21 mm."

#### Genus *Cronius* Stimpson, 1860

*Cronius ruber* (Lamarck) 1818 (Red Swimming Crab).

*Portunus ruber* Lamarck, *Hist. Nat. Anim. sans Vert.*, vol. 5, p. 260, 1818.  
*Cronius ruber* Stimpson, *Ann. Lyc. Nat. Hist. N. Y.*, vol. 7, p. 225, 1860.  
*Achelous ruber* A. Milne Edwards, *Arch. Mus. Hist. Nat. Paris*, vol. 10, p. 345, pl. 23, fig. 1, 1861.  
*Cronius ruber* Rathbun, *Zoologica*, N. Y. Zool. Soc., vol. 5, No. 14, p. 159, 1924.

*Diagnostic characters.*—Carapace subcircular; postorbital spine wider basally than any of the succeeding anterolateral spines.

*Type.*—Lamarck's type which is believed to be no longer extant, came from the "Antilles."

*Galapagos distribution.*—Off Eden Island, 5 fathoms (Harrison Williams Expedition), three young specimens.

*General distribution.*—This species ranges from Charleston, South Carolina, to Rio de Janeiro, Brazil, on the Atlantic coast and from Lower California to Ecuador on the Pacific coast.

*Material examined.*—One young specimen collected off Eden Island, in five fathoms, April 1, 1923, by the Harrison Williams Galapagos Expedition (tag 2075).

*Technical description.*—(The following notes were made from a young specimen which is only 6.5 mm. long.)

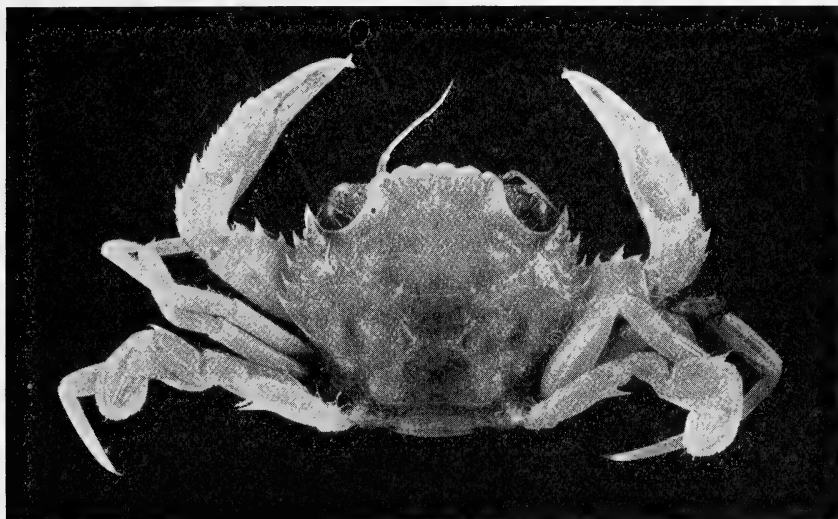


Fig. 62. *Cronius ruber*, young  $\times 5$ .

Carapace almost subcircular, 6.5 mm. long, 7 mm. wide from tip to tip of lateral spines. Interorbital space 3 mm. wide, divided into six lobes including the preorbital pair, of which the median pair are smallest and closest together; the second pair are broader and are separated from the median pair by a wider sinus than the median pair are from each other, or than the second pair are from the preorbital pair, to which they are subequal. The entire frontal margin is finely crenulated and sparsely setigerous. The orbit is subelliptical; marked on the superior margin by three suture lines indicating sinuses. The outer half of the superior orbital margin is fringed like an eyelash. The postorbital spine is triangular, acute, wider basally than any of the other orbital spines; there is a small, inferior, blunt spine on the base of the posterior margin of the postorbital spine. The postorbital spine is followed by similar, subequal, acute, triangular spines, each of which is narrower basally than the postorbital spine. The first spine behind the postorbital spine bears a smaller rudimentary blunt tooth at the base of its posterior margin. All the anterolateral spines are forward-directed. The dorsal surface of the carapace is finely setigerous. There is a

beadlike line on the median gastric area behind and subparallel to the inter-orbital space. Another beadlike line curves inward between the bases of the third and fourth lateral spines and vanishes approximately opposite and posterior to the outer ends of the above-mentioned median gastric line. Both bear an anterior fringe of fine short setae. The postlateral margins of the carapace are convergent.

The cheliped has three large and two minute (basal) spines on its superior anterior margin; the carpus bears a strong, sharp spine at its inner distal angle, an obtuse, beaded outer distal angle, below which there is another sharp, sub-distal spine which is followed posteriorly by a small, sharp spine on the upper surface of the carpus; the inferior distal angle of the carpus also bears a small sharp spine. The propodus is finely granulose; its inner upper margin bears two large acute spines one of which is almost midway its length, the other, smaller one is subdistal; a second carina of denticle-like tubercles extends along the outer margin and terminates in an acute subdistal tooth; the convex outer surface is traversed by three longitudinal carinae, the upper one is composed of sharp denticles and ends approximately above the base of the hinged finger; the second carina is composed of smaller granules and is approximately parallel to the upper one, but ends between the fingers; the third carina is the longest, extending almost to the distal end of the propodal finger. The fingers are sub-equal, comprising two-fifths of the propodal length; fluted on the outer surface; tips acuminate, crossing upon each other.

Family: XANTHIDAE

Subfamily: XANTHINAE

Genus *Liomera* Dana, 1851.

*Liomera cocosana*, *sp. nov.*

*Name*.—This species takes its name from Cocos Island, where it was first discovered.

*Diagnastic character*.—Carapace barrel-like, convex, anterolateral margins four lobed. Male chelipeds with black fingers and a heavy median black band on the propodus.

*Type*.—The type, an adult male and female specimen were taken at Cocos Island, May 9, 1925, by the Arcturus Oceanographic Expedition. It is deposited in the collections of the New York Zoological Society.

*Galapagos distribution*.—Arcturus station 54, Gardner Bay, off Hood Island, 15 ft., coral rock bottom.

*General distribution*.—Cocos Island and Hood Island, Galapagos Islands.

*Technical description*.—Carapace barrel-like, strongly convex in both directions; surface enamel-like, shining, with numerous rather coarse punctae irregularly scattered over the surface; the frontal margin is bilobed by a definite median notch and short sulcus, on either side of which it is sinuate forming a broad rounded submedian lobe which is succeeded by a less produced outer lobe which is almost right-angled and closely appressed to the eye-stalk. The anterolateral margin is divided into four rounded lobes of which the first, or

postorbital is almost colaesced with the second lobe, only a short marginal sulcus which is scarcely visible dorsally indicating the division; the third lobe is more definitely rounded than the preceding one, from which it is separated by a decided sulcus which extends inward on the branchial region; the fourth lobe is slightly larger than the third from which it is separated by a sulcus similar to that between the second and third lobes; posteriorly the fourth lobe is contiguous with the posterolateral margins which are decidedly concave



Fig. 63. *Liomera cocosana*, male  $\times 3$ .

and convergent. The male abdomen is five-segmented, the first and second segments being successively narrower but subequal in length; the third, fourth and fifth segments are anchylosed forming the third segment which narrows distally; the penultimate segment is squarish, half as long as the preceding segment; the terminal segment is triangular with the apex rounded. The female abdomen is broadly oval, seven-segmented, the sixth and seventh segments being the longest.

The superior orbital margin is closed, with two very faint suture lines indicating closed sinuses.

The eye-stalk is short and stout and produced distally on the inner side as far as the cornea, which latter is quadrispherical, shining black; apparently with a very limited range of vision.

The antennulae are stocky and fold nearly transversely within the septum.

The antennae have the basal joint short and wide, tapering distally, just touching the frontal margin; the flagellum lies within the orbital hiatus. and extends almost to the distal margin of the eyestalk.

The external maxillipeds have the exognath half as wide as the ischium basally, tapering moderately distally to a point at the outer distal angle of the merus, and supporting a small slender multiarticulate whip, which is internal; the ischium is rectangular, two-thirds as wide as long, with a median longitudinal groove on the outer face, and with the distal margin slightly oblique; the merus is approximately half as long as the ischium, with the distal margin moderately oblique and the inner distal angle notched for the reception of the three-jointed palp which is stocky and set with numerous long setae.

The chelipeds are subequal in both sexes with the three proximal joints small, the merus much longer reaching almost to the outer edge of the carapace, trigonal; the carpus is almost as long as the merus with the upper and outer surfaces rounded; the propodus is distinctly the largest joint of the limb, the palm being somewhat longer and higher than the carpus, and having a proximal ball-like base separated from the rest of the palm by a sharply defined crescentic margin; the remaining outer surface of the palm is moderately convex with a longitudinal groove somewhat below the upper margin, and a second less pronounced groove approximately halfway the distance below the first groove; the propodal finger is about half as long as the palm and is quite slender and tapering, armed with a single median tooth on the cutting edge, and having a prominent groove on outer face which in the male extends back a short distance on the propodus. The hinged finger is somewhat thicker and more curved than the propodal and has two deep grooves on its outer surface.

The chelipeds of the male type, have both fingers a rich black, this color being continued from the base of the propodal finger backward on the palm for half its length and upward to the dorsal margin as a slightly narrowing band, on both the inner and outer faces of the propodus; a bright orange-red area separates this black band from the base of the hinged finger. In the female type only the fingers are black, the entire propodus being of the same color as the carapace. The female chelipeds seem a trifle less robust than those of the male.

The ambulatory legs are similar but successively decrease in length from the first to fourth pairs. Each has the meral, carpal and propodal joints stout and the dactyl slender, long, a little curved and banded with cream-color just before the tip which is black.

#### Genus *Leptodius* A. Milne Edwards, 1863

##### Key to the Galapagos species of the genus *Leptodius*

Anterolateral margin obtuse and rounded; postorbital and first marginal tooth obscure, coalesced; the second, third and fourth teeth are raised lobes. Carapace deeply areolated.

*cooksoni*

Anterolateral margin broken into four well marked teeth, besides the postorbital tooth; carapace deeply areolated on the anterior two-thirds.

*snodgrassi*

*Leptodius snodgrassi* Rathbun.

*Leptodius snodgrassi* Rathbun, *Proc. Wash. Acad. Sci.*, vol. 4, No. 8, p. 279, pl. 12, figs. 7 and 8, 1902; *Proc. U. S. Nat. Mus.*, vol. 38, p. 582, 1910.

*Name:* This species appears to have been named for Mr. Robert E. Snodgrass, one of the naturalists of the Hopkins-Stanford Galapagos Expedition.

*Diagnostic characters.*—Frontal border bilaminar; anterolateral border with four well-marked teeth besides the orbital tooth; carapace deeply areolated on its anterior two-thirds.

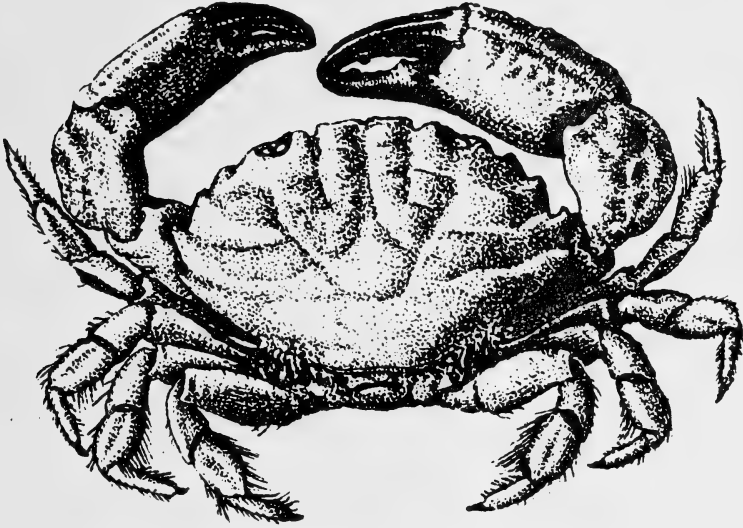


Fig. 64. *Leptodius snodgrassi*,  $\times$  about 3 (After Rathbun).

*Type.*—The type of this species and a fragment of a smaller specimen was secured at Black Bight, Albemarle Island; one small cheliped of a small specimen was taken at Tagus Cove, Albemarle Island.

*General distribution.*—Known only from Galapagos.

*Material examined.*—None.

*Technical description.*—I have not been able to secure a specimen of this species for examination and am therefore quoting Dr. Rathbun's description of the type:

"Carapace moderately convex and deeply areolated in its anterior two-thirds, flat and smooth in its posterior third. Behind each lobe of the frontal margin a small lobule; behind each of these a larger and very prominent rectangular lobule; still further back a transverse line of four high gastric lobules, the outer pair about one and a half times as wide as the inner; and behind these a granulated line of granules interrupted at the middle, across the widest part of the mesogastric region. The lateral portions of the carapace have each four prominent elevations, one of which is nodular and situated at the base of the fourth antero-lateral tooth, and three of which are surmounted by broad trans-

verse ridges; of the three ridges the anterior is in a line with the third lateral marginal sinus, the second ridge is in a line with the fourth sinus, while the third is posterior to the last marginal tooth. Front not very prominent, but projecting beyond the inner angle of the orbit, from which it is separated by a notch; bilaminar, the lobes with a slightly concave margin, and most prominent at the inner end. Antero-lateral border cut into four well-marked teeth besides the orbital angle; the first tooth is blunt and situated below the level of the orbital tooth, with which it is connected by a blunt superior ridge; the remaining teeth are acute, the third and fourth very prominent. Lower surface of carapace, edges of upper surface of arm and edges of legs hairy, especially the lower edge of the propodus of the last pair.

Chelipeds very unequal in the male. Upper and outer surface of wrists deeply dimpled or wrinkled; a strong tubercle at inner angle of wrist. Hand with blunt longitudinal carinae, two on the upper margin and three on the outer surface. The upper carina of the outer surface is broad and has a row of deep pits or dimples; the lowest carina is at the inferior third of the outer surface and is continued along the upper margin of the thumb. The upper part of the inner surface is also pitted. The entire surface of the chelipeds as well as of the carapace is finely and closely granulate and irregularly punctate. The fingers are carinated, the lower carina on the outer surface of the thumb is continued one-third the length of the palm. The fingers are black and the color of the thumb is extended on the palm, ending in a zigzag line. The fingers of the large hand gape widely, those of the small hand slightly; dactylus of large hand with two large teeth and a small intermediate one; pollex with two large teeth; tips broadly hollowed out, fingers of small hand with wavy margins. Ambulatory legs flattened, and more or less granulate, the granules fine and forming rugae. Carpal and propodal joints with a longitudinal groove. Dactylus furred along the edges as far as the nail. Abdomen of male five-jointed."

"*Dimensions*.—Length 13.1 mm. width 20.4, fronto-orbital width 11.8, width of front 5.5."

*Leptodius cooksoni* Miers.

*Leptodius cooksoni* Miers, *Proc. Zool. Soc. London*, p. 73, pl. 12, figs. 1-1d, 1877; Rathbun, *Proc. U. S. Nat. Mus.* vol. 38, p. 582, 1910.

*Diagnostic characters*.—Carapace finely punctate, anterior region distinctly areolated. Frontal margin bifid; anterolateral margins obtuse and rounded, the postorbital tooth and the first marginal tooth are obscure, coalesced, the second, third and fourth teeth are raised lobes.

*Type*.—Miers founded this species on an adult male and a smaller female specimen taken at Charles Island.

*Galapagos distribution*.—Charles Island (type-locality); *Arcturus* station 54, off Hood Island, depth 15 feet.

*General distribution*.—Known only from the Galapagos Islands and Cocos Island.

*Material examined*.—Seven females, three of which are ovigerous and nine males from Cocos Island; five males and six females taken at station 54, off Hood Island, by William Beebe, while diving in 15 feet, of water.

Carapace ovate, convex, deeply areolated; regions clearly defined; 16 mm. long, 27 mm. wide; interorbital space one-third of width of carapace, with frontal margin raised, slightly produced and minutely bilobed in the median line; frontal edge arcuate with the angle near the orbit bent downward. The orbit is subcircular with an internal hiatus; the dorsal rim is raised. The anterolateral margins are broadly rounded, broken into five teeth, the first and second of which are long, obtuse, coalesced except for a faint dorsal constriction; third



Fig. 65. *Leptodius cooksoni*,  $\times 2$ .

tooth is about as long as second, but is raised and produced anteriorly to a triangulate tooth; the fourth tooth is also raised to form a triangulate tooth but is not so wide as the third one; the fifth one is raised but is much less prominent than the preceding one. There is a groove-like line just inside these teeth paralleling the lateral margin, which accentuates the lobes of the carapace. The gastric region is delineated by deep grooves which run back from near the outer edge of the orbit to the join urogastric groove. The groove running back from the median frontal notch bifurcates to outline the mesogastric area. A short groove runs from the inner orbital angle back a short ways bilobing each half of the gastric region. A curved groove runs inward from between the second and third lateral teeth, the cervical groove—defining the hepatic



lobe; a second groove runs inward from between the third and fourth teeth and fuses with the above described groove about midway its length. A more deeply delineated groove runs inward from between the fourth and fifth teeth and fuses with the urogastric depression, thus forming a complete transverse sulcus across the carapace. The postlateral margins are slightly arcuate, convergent. The posterior margin is a flat, raised carina; paralleling it, separated only by a narrow groove is a raised, slightly wider ridge which terminates into a rounded, low tubercle at each end.

The male abdomen consists of five segments; the first and second segments are narrow, dorsal in position; the second is one half as long as the first segment; the third, fourth and fifth segments are fused into one which is produced laterally at the basal end completely covering the sternum between the first and second legs, thence curving inward and narrowing as it goes forward, uniting with the sixth segment midway the basis of the second ambulatories; the sixth segment is squarish with the frontal border arcuate; the seventh segment is only about half as long as the sixth and forms a small triangle whose apex is blunt. There is a median longitudinal slit-like depression on the sternal plate, just a little in front of this apex of the abdomen. The first pair of male appendages are stout, basally curving inward and proceeding forward as strong, slender rods, laterally compressed and channeled on the inner side. This channel is margined on either side by a row of finely denticulate granulations; the tip of the organ is flattened, rounded and produced outwardly into a transparent, corneous, subspatulate process whose edge is finely crenulate. There is a long brush of setae on the inner margin of the rod near the base of this process. The second male appendages are very short, produced basally into a curious winglike process which is fringed outwardly with setae and continues distally as a fine curved rod that only reaches forward to the beginning of the rod of the first appendages.

The outer antennae have the basal articles closely fused with the epistome; the three free peduncular articles cylindrical, successively decreasing in size distally; the flagellum is minute, consists of eight tapering articles and reaches only to the base of the cornea. The first basal antennal segment forms a ball-like movable aperture for the antennal gland—the free margin of this segment is finely setose and fits tightly upon the epistome when closed; when opened it reveals its inner wall and cuplike cavity.

The inner antennae are stout, clavate and fold obliquely within the septum. The orbit is subcircular; the eyestalk is dilated basally, constricted distally on the outer surface and its margin is finely granulate; on the upper surface the margin is produced into a rounded piece which projects on the cornea, is small, convex, elliptical, placed transversely at outer end of the stalk.

The external maxilliped is rectangular, close-fitting except for an irregularly shaped slit at the efferent aperture. The exognath has a very small base, a long rod-like merus and an internal whip. The endognath has a rectangular ischium marked by a longitudinal sulcus; a squarish depressed merus which has the outer distal angle somewhat produced and the inner angle deeply incised for the reception of the rotund basal joint of the three-jointed palp whose tapering second and third joints are bent downward beside the inner meral margin. The inner margin of the ischium, and the upper margin of the merus and the

palp are fringed with setae. The outer surface of the maxilliped, especially of the merus, is finely granulose,—that of the merus is also setigerous.

The sidewalls of the carapace under the legs bear dense tufts of long plumose hairs.

The male chelipeds are moderately subequal, both being massive. The large cheliped has the basis and ischium small; the merus long, three-sided, exceedingly compressed laterally except at the distal end which is produced at its inner dorsal angle into a curious rounded socket-like process into which a knob of the carpus fits; a crooked sulcus round this process and extends inward on the inward side of the merus; the carpus is very prominent, swollen distally, rugose and convex on the upper and outer surfaces, and produced to a blunt knob at the inner dorsal angle; the propodus is massive, twice as long including the finger, as the carpus, and as high as the carapace; rugose on the dorsal and upper half of the outer surface, small on the lower; the finger is two-fifths the total length of the propodus, and tapers to a rounded point which is hollowed, spoon-shaped and bears a tuft of hairs in the concavity. In addition to this there are three small distal teeth and two large basal molars. The finger is slaty black and carinated longitudinally on the outer surface. The hinged finger is more curved distally but otherwise resembles the propodal except that it has only one very large molar which is followed by two medium sized and eleven insignificant teeth and a tuft of setae in the concavity of the spoon-tip. The fingers are gaping, except at the tips which fit perfectly upon each other. The inferior chela differs only from the superior in size and in having the fingers longer, slenderer not gaping; they comprise about one-half the length of the propodus.

The ambulatories are similar, subequal, gradually decreasing slightly in length posteriorly. The first pair has the merus arched toward the front, the second, third and fourth pairs curve posteriorly. The merus is the longest joint and is compressed; the carpus and propodus taken together are about as long as the merus but are stouter and more dilated; the dactyl is slenderer, compressed cylindrical, tipped with a strong horny nail and covered with coarse setae, which also form a brush on the under margin of the propodus.

#### Genus *Xanthodius* Stimpson, 1859

##### Key to the Galapagos species of the genus *Xanthodius*

- Anterolateral margin deeply quadridentate. *occidentalis*  
 Anterolateral margin divided into four prominent lobules; carapace deeply lobulated, sulci between the lobules deep and wide. *lobatus*

*Xanthodius lobatus* (A. Milne Edwards). One of the group known as "pebble" crabs.

*Leptodius lobatus* A. Milne Edwards, *Crust. Rég. Mex.*, p. 271, pl. 49, fig. 4, 1880.

*Xanthodius lobatus* Rathbun, *Proc. U. S. Nat. Mus.*, vol. 38, p. 582, 1910; *Zoologica*, N. Y. Zool. Soc., vol. 5, no. 14, p. 158, 1924.

*Diagnostic characters*.—Carapace deeply lobulated, sulci between the lobules deep and wide. In life a broad band of contrasting color (white in preserved specimens) down the middle of the back.

*Type*.—Professor Milne Edwards' type material came from the "coasts of Chile" and is deposited in the Paris Museum.

*General distribution*.—In addition to the type-locality, Chile, this species is known from the Galapagos Islands, Cocos Island, and Clarion Island, Mexico.

*Material examined*.—One female and six males from Station 54, off Hood Island, taken by William Beebe, while diving in 15 feet of water; five males and

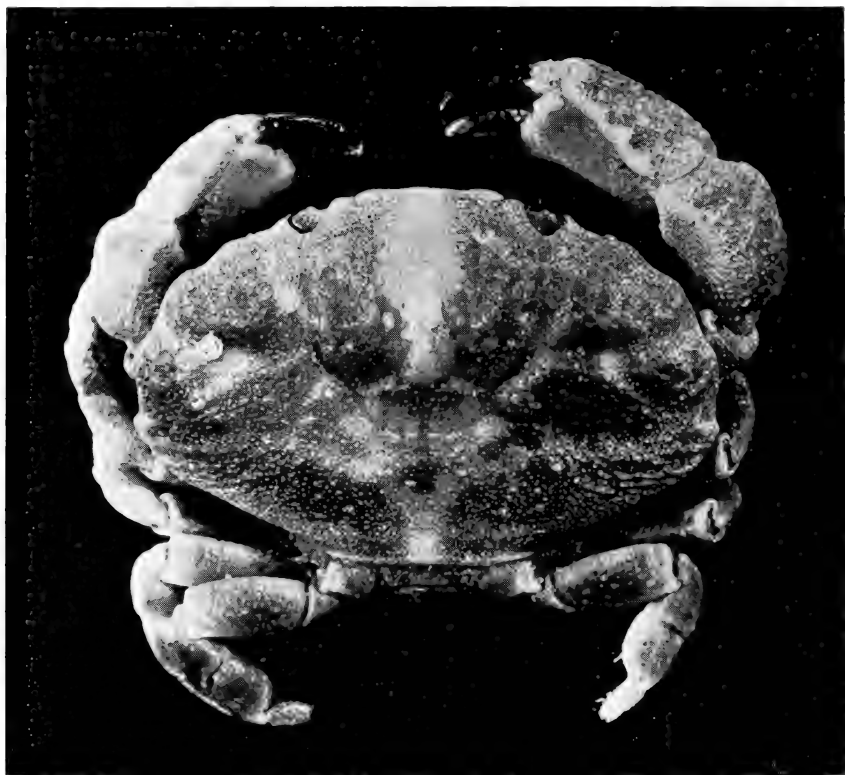


Fig. 66. *Xanthodius lobatus*,  $\times 4\frac{1}{4}$ .

six females (one of which is ovigerous) also one fragment, from Cocos Island; one female (photographed, fig. 66) from Station 37, shore zone, D to E, Tower Island, April 10, 1925.

*Habits*.—This species dwells in the crevices of the coral rock bottoms.

*Technical description*.—Carapace 11 mm. long, 17.6 mm. wide, very convex and deeply lobulated with the depressions between the lobes deep and wide. Interorbital border 6 mm. wide, deflexed, sinuate, carinated and separated from the median lobes by a sinuate depression which is confluent with a median groove that runs back posteriorly between the median lobes and bifurcates

outlining the mesogastric region. There is a deep longitudinal sulcus bisecting each median lobe, which is confluent with a curved sulcus behind the raised superior orbital margin. The cervical grooves are very deep, they arise behind the eye, bisect the postorbital sulcus, outline the outer pair of median lobules and converge with the grooves delineating the cardiac region. The antero-lateral border is divided into four prominent lobes; the hepatic lobe is moderately developed; the second lobe is a trifle larger; the third lobe is the largest and most prominent; the fourth lobe is small and somewhat pointed. Sub-parallel to the anterolateral margin are a series of pit-like depressions which accentuate the rugose appearance of the first, second and third lobes. A curved depression passes inward from between the first and second lateral lobes and unites with the postorbital depression. A second broken depression passes inward from between the second and third lateral lobes and unites with the cervical groove. A more incisive depression passes inward from between the third and fourth grooves, and uniting with the urogastric groove, forms a complete transverse depression across the carapace. Two short oblique grooves cross the third lobe uniting with the second and third grooves and cutting the third lateral lobe into three lobes. Posterior to the fourth lateral tooth are three or four granulose striae, separated by short, broken depressions. The posterior margin is sinuous, granulose, carinated, paralleled by a groove followed by a second, broken raised carina. The under sides of the carapace are heavily granulose.

The female abdomen is oval, rather narrow, seven-segmented and fringed with short thick setae. The first and second segments are visible dorsally and are rather narrow; the third, fourth and fifth segments are a trifle longer than the second and are subequal; the sixth segment is one and one-half times as long as the fifth; the seventh segment is about two-thirds as long as the sixth and has its anterior margin bluntly rounded. The second to fifth segments inclusive respectively bear paired biramose appendages to which the eggs are attached. The outer branch is curved; the inner branch consists of a basal joint which is obliquely directed toward the center and which supports a six-segmented joint which is forward-directed and heavily fringed.

The male abdomen is narrow, triangulate and consists of five articulations, the third articulation being composed of three anchylosed segments; the terminal segment is rounded distally.

The first pair of male appendages are very stout basally tapering into a substantial rod which is grooved on its outer surface, each raised edge, or side, of the groove being finely serrate; distally the process widens into a spoonlike process which is convex and heavily spinose on its under side, produced to a twisted tip distally, and concave on its upper surface, this concavity being confluent with the groove of the rod.

The eyestalk is short and bulbous, filling the orbit; constricted on its upper surface and produced distally into a small rounded process on the dorsal surface of the cornea; the cornea is small, terminal, scarcely deep enough to be called hemispherical.

The internal antennae are large and fold obliquely with the fossett which lies beneath the frontal border; the basal article is very large and of a peculiar

shape; the two succeeding articles are cylindrical, the terminal one is swollen distally and bears the small two-branched flagellum.

The external antennae are situated in the inner inferior orbital hiatus; the immovable joint is subrectangular, twice as long as wide; the first free joint is very small, cylindrical, transversely constricted on its outer surface; the second free joint is also cylindrical, and scarcely larger than the flagellum; the latter consists of fourteen tapering articles, and extends only to the base of the cornea.

The external maxillipeds are rectangular, being one-fourth wider than long, and fit closely into the buccal cavity. The ischium is subrectangular and is traversed on its outer surface by a deep longitudinal groove; the merus is half as long as the ischium, but is wider distally with the outer distal margin produced; the outer surface is grooved irregularly; the inner distal margin of the merus is notched for the reception of the palp; the latter has the basal joint stout, the second and third joints being successively smaller and tapering to a point which bears an unusually long brush of setae. The inner margin of ischium and merus are setose; their outer surfaces are very granulose and finely setigerous.

The chelipeds are equal and are alike in both sexes. They fit closely against the sides of the carapace. The upper and outer surfaces of the meral, carpal and propodal joints are convex and deeply pitted and granulose, having a coarse, eroded appearance. The upper edge of these three joints is sharply ridged, the inner surfaces being flat, fairly smooth and closely appressed to the body. The basal three joints are small; the meral joint does not extend beyond the carapace; the carpal joint is quite large, being nearly as long as the palm, and is produced to a sharp angle on its inner subdistal margin. The palm is high, angulated on its upper margin, eroded on its upper surface and the upper half of its outer surface and coarsely granulose on the lower half of the outer surface, there being three or four longitudinal carinae composed of granules in this region. Both fingers are deep brownish black; are spoon-shaped at the apex and fit upon each other; the cutting edges nearly meet. The propodal finger is about one-third of the length of the propodus and is longitudinally traversed by continuations of the two lower carinae of the propodus; there are three large teeth on the cutting edge, the median one being the most prominent. The hinged finger is similar to the propodal but is more curved; it is traversed by two deep sulci, the more prominent of which is on the upper surface. There are three shallow triangulate teeth on the cutting edge, all being inferior in size to those of the propodal finger. Within the concavity of the spoon-like apex of both the propodal and hinged fingers there is a round cavity from which arises a tuft of long bristly setae.

The four pairs of ambulatory legs are similar, rather short and stubby. The first three pairs are subequal in length; the fourth pair is smaller, reaching only to the distal part of the propodus of the third pair. All have the basal three joints small, the meral, carpal and propodal joints stout, compressed cylindrical, and granulose on the outer surfaces; the dactyl is compressed cylindrical also, and as long as the propodus, terminating in a sharp spine. The dactyl is covered with short, furry setae in which long spinose setae are sparingly interspersed.

*Eggs*.—A female 8 mm. long carried about 340 eggs. These were pale yellow spheres.

*Young*.—Young specimens of *Xanthodius lobatus* 3.7 mm. wide show only faint indications of the lobed carapace, but may be identified by the chelae, which correspond to those of the larger adults. Specimens 6 to 8 mm. wide show clearly all the characteristics of the larger specimens, except that the smaller ones are finely granulose and lack the eroded appearance of the older forms.

*Xanthodius occidentalis* (Stimpson).

*Chlorodius occidentalis* Stimpson, *Ann. Lyc. Nat. Hist. N. Y.*, vol. 10, p. 108, 1871.

*Leptodius occidentalis*, A. Milne Edwards, *Crist. Rég. Mex.*, p. 269, 1880; Rathbun, *Proc. U. S. Nat. Mus.*, vol. 21, p. 589, 1899.

*Xanthodius occidentalis*, Rathbun, *Bull. American Mus. Nat. Hist.*, vol. 48, p. 622, 1923.

*Diagnostic characters*.—Lateral margin quadridentate (in addition to post-orbital tooth); anterior two-thirds of carapace deeply areolated and lobulated.

*Type*.—Professor Stimpson's type material was "found at Panama by Alexander Agassiz, Esq., and at Manzanillo, Mexico, by Mr. John Xantus."

*Galapagos distribution*.—Galapagos Islands.

*General distribution*.—Manzanillo, Mexico; Aqua Verde Bay and Pichilique Bay, Lower California; Panama and the Galapagos Islands.

*Material examined*.—One specimen from station 54, Gardner Bay, off Hood Island, Galapagos Islands, in 15 feet of water.

*Technical description*.—Carapace 17 mm. long; greatest width 25 mm.; decidedly convex, deeply areolated and lobulated between the areolations. The frontal border is equal to a little more than one-third the width of the carapace and is relatively straight and not produced in advance of the lateral teeth. A small median notch separates the two frontal lobes; their outer angles are almost right-angled and separated from the preorbital angle by a V-shaped sinus; the superior orbital margin is elliptical and is cut by two lines indicating closed sinuses. The postorbital angle is a blunt triangulate tooth; a small submarginal hepatic tooth shows below the hiatus between the postorbital and first anterolateral tooth. The anterolateral margin is cut into four distinct teeth; the first (most anterior) tooth is three-fifths as wide as the orbit and is blunt; its anterior lateral margin being short, its posterior lateral margin long and rounded. The second tooth is of similar shape as the first and is the broadest of the series, being as wide as the long diameter of the orbit; the third tooth is almost as wide as the second tooth and is decidedly more acute, with its apex forward-directed and its longer postlateral margin rounded; the fourth tooth is also acute but is smaller than the third tooth and outward-directed, with a moderately carinated midrib running inward from the apex. The cervical, hepatic, cardiac and urogastric grooves are deep. There is also a groove running inward between the second and third teeth and another similar groove between the third and fourth teeth. A submarginal groove runs between the lateral teeth and the branchial lobules. The second and third lobules are also crossed by diagonal depressions. The posterior margin is carinated. The pterygostomial region is tomentose. The entire dorsal surface of the carapace is coarsely punctate.

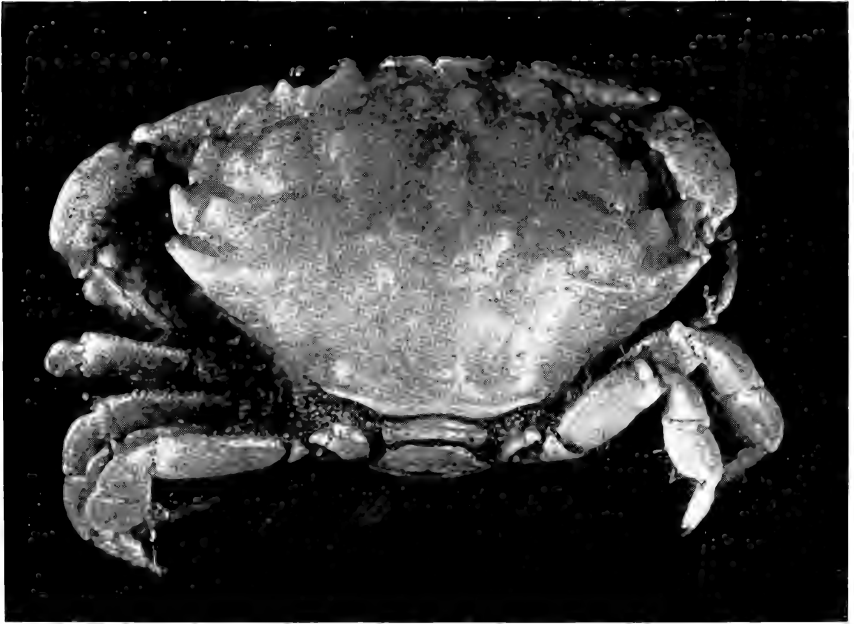


Fig. 67A. *Xanthodius occidentalis*, female, dorsal view  $\times 2.8$ .

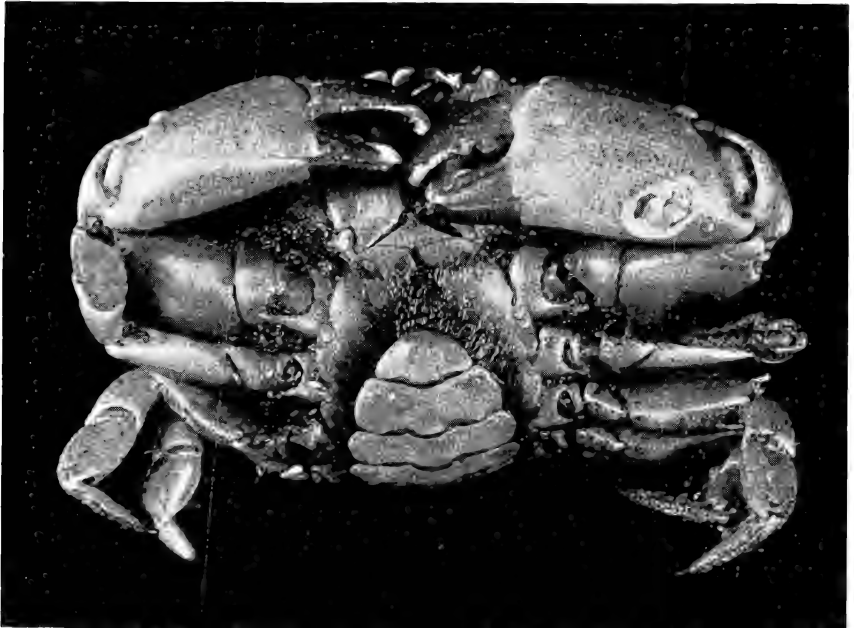


Fig. 67B. Same, ventral view.

The eyestalk is short, cylindrical, constricted on the dorsal surface below the cornea and produced to a small subcircular process that extends upon the cornea; the cornea is subspherical, brownish-black.

The inner antennulae are well developed and fold within the fossett beneath the rostrum.

The external antennae have the basal article enlarged and closely fitted into the hiatus; the second and third articles are successively smaller; both are situated in the orbital hiatus; the flagellum is composed of eight tapering rings and extends to the base of the cornea.

The external maxillipeds offer no specific characters.

The chelipeds are slightly unequal in the female. The merus is trigonal, decidedly compressed on its dorsal surface, and curved; the carpus is quite convex dorsally, and areolated; there is an acute subdistal tooth at the inner distal angle; the propodus is long, convex on its outer face with the upper region a little roughened; the fingers are deep brown, subequal, curved, with the tips spoon-shaped. The propodal finger of the large cheliped has a large subdistal tooth.

The ambulatory legs are similar and successively decrease in length in the order 1, 2, 3, 4. Each leg has the merus, carpus and propodus dilated, the dactyl stout and covered with short bristles.

#### Genus *Cycloxanthops* Rathbun, 1897

*Cycloxanthops vittatus* (Stimpson) (Cameo Crab).

*Xantho vittata* Stimpson, *Ann. Lyc. Nat. Hist., N. Y., vol. 7, p. 78, 1860.*

*Cycloxanthus vittatus* A. Milne Edwards, *Miss. Sci. au Mexico, p. 259, pl. 46, fig. 5, 1880.*

*Diagnostic characters.*—Frontal border equal to about one-fourth of the width of the carapace and very prominently projecting beyond the anterolateral border. Anterolateral margin with seven acute teeth; one smaller postlateral tooth.

*Type.*—Professor Stimpson's type material, which is no longer extant, "was found at Panama by the Rev. J. Rowell also abundantly at Cape St. Lucas by Mr. Xantus."

*Galapagos distribution.*—Off Hood Island, *Arcturus* station 54, from a depth of 15 feet.

*General distribution.*—Known only from the type material taken at Panama, and Cape St. Lucas, Lower California, and the material taken at Galapagos by the *Arcturus*.

*Material examined.*—One large female and four very young specimens were secured by William Beebe, while diving in 15 feet of water at station 54, off Hood Island, Galapagos. These specimens are deposited in the collections of the New York Zoological Society, New York City. They appear to be the first record of this species from the Galapagos Islands, and also the first capture of the species, since the type material, which is no longer extant, was taken.

*Technical description.*—Carapace ovate, moderately convex, regions clearly delineated, 12 mm. wide, 10 mm. long. Frontal border equal to about one-fourth of the width of carapace, produced beyond the anterolateral border;



very prominent; margin finely crenulate, minutely bilobed by a median indentation which is continued as a distinct groove back upon the gastric region. Orbit with four prominent subequal teeth forming the upper margin. Anterolateral margin with seven (in addition to the postorbital) unequal, acute, raised teeth. The first tooth is about as far behind the orbit as the width of the orbit and is acute; the second tooth is the largest of the series; the third is about equal to the first, but slightly sharper, the fourth tooth is only about half the



Fig. 68. *Cycloxanthops vittatus*,  $\times 5$ .

size of the third; the fifth tooth is about as large as the third, the sixth tooth is small like the fourth and the seventh tooth is only a trifle larger and sharper than the fourth. There is a minute granulation faintly resembling a tooth on the postlateral margin posterior to the seventh tooth; otherwise the postlateral margins are unornamented, slightly arcuate and decidedly convergent. In addition to the median sulcus there is a sulcus on each side running backward from the inner orbital angle and another from between the second and third orbital teeth. The anterior part of the carapace is faintly granulose. It is traversed by two broken lines of somewhat larger granulations, the anterior of which ends near the third lateral tooth; the second line is just behind the

first one. There is also a line composed of granulations running inward from the fifth lateral tooth as far as the outermost longitudinal sulcus. A second, higher unbroken line runs inward from the sixth lateral tooth about the same distance. The pterygostomian region is traversed by a line of long setae; the sides of the carapace adjacent to the basal joints of the legs are smooth.

The lower half of the orbit consists of two teeth, the inner of which is the more prominent.

The female abdomen is seven-segmented, segments one and two being narrow, short and dorsally visible; segment three is the widest projecting beyond the other segments as triangulate formations, segments four and five are subequal; segment six is squarish, being decidedly longer than any of the preceding segments; segment seven is almost an equilateral triangle. Four pairs of biramous appendages are borne by the second to fifth segments respectively.

The outer antennae have the basal article squarish with the distal margin arcuate, fitted into the space between the orbit and epistome; the second article is cylindrical, moderately stout, the third slender; the flagellum consists of about fourteen tapering rings.

The inner antennae are fleshy and fold obliquely within the septum which is overarched by the projected frontal border.

The eyestalk is stocky, constricted on the outer side, calcareous like the carapace and produced in front to a tubercle at the edge of the cornea and a second less protuberant process projects upon the upper surface of the cornea. The latter is terminal, transversely placed, convex, black.

The external maxillipeds have a slender two-jointed exognath which bears a slender whip internally; the endognath consists of a subrectangular ischium and five-sided merus set obliquely, and supporting a palp consisting of a broad basal, a moderate second and a finely tapering third joint. The upper and inner margins of the articles of the maxilliped are very setigerous.

The chelipeds are equal. The basis and ischium are small, the merus quite long and very broad and fringed with hairs along the ventral margins. The carpus is rather long, dilated distally, convex on the outer surface and bears a tooth at the upper, inner distal angle; the propodus is massive, moderately convex on the outer surface, flattened along the dorsal margin and terminating distally in a rounded knob-like process above the hinged finger. The propodal finger is triangular, bears two linear carinations on the outer surface and four well-developed teeth along the cutting edge. The hinged finger is very similar to the lower finger in shape but bears eight small teeth along the cutting edge, a curved linear carina on the outer surface, and another carina on the outer dorsal edge. The first three pairs of ambulatories are similar and subequal, the fourth pair is conspicuously shorter than the preceding. All have the merus long and arched to conform to the body contour, the carpus and propodus short, the latter being dilated, the dactyl long and slender, being as long as the propodus, tipped distally with a horny point, finely setigerous on the upper, and coarsely so, on the lower surface. The upper and lower margins of the propodus and carpus are also setigerous.

*Young*.—A specimen of this species measuring 1.8 mm. long, 2 mm. greatest

width, possesses all the characters of the older form, but as is usual with very young crabs, the eyes are relatively much larger and more prominent.

### Genus *Medæus* Dana

Key to the Galapagos species of the genus *Medæus*.

Ambulatory legs with lobate crests.

*lobipes*

Ambulatory legs without crests of any kind.

*rugosus*

*Medæus lobipes* Rathbun.

*Medæus lobipes* Rathbun, *Proc. U. S. Nat. Mus.*, vol. 21, p. 583, pl. 44, fig. 1, 1899; *Proc. U. S. Nat. Mus.*, vol. 38, p. 583, 1910.

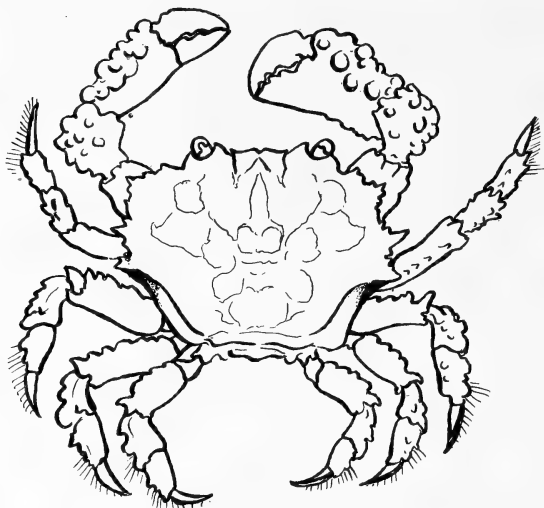


Fig. 69. *Medæus lobipes*,  $\times 1\frac{1}{2}$  (After Rathbun).

*Diagnostic characters*.—Ambulatory legs with lobate crests. (Rathbun.)

*Type*.—One male, from Panama Bay, *Albatross* station 2796, 33 fathoms deposited in the United States National Museum.

*Galapagos distribution*.—Off Hood Island, 20 fathoms (one female).

*General distribution*.—Off Cape St. Lucas, Lower California, 31 fathoms; Panama Bay,  $5\frac{1}{2}$  to 33 fathoms; Galapagos Islands.

*Material examined*.—None.

*Technical description*.—The following is the original description of the species:

“Carapace shorter and broader than in *Medæus spinimanus* Milne Edwards; lobules similar in shape and position to those of that species. In the largest specimen the tuberculation of the lobules is less extensive than in the somewhat larger individual of *Medæus spinimanus*, with which it is compared. Posterior half of mesogastric region divided by a median sulcus into two lobules. Cardiac region also distinctly divided in the same way. Front less advanced,

and lobes less oblique than in *Medaeus spinimanus*. The lateral teeth and the chelipeds offer no differences worthy of note. The ambulatory legs are, however, very distinct. They are shorter than in *Medaeus spinimanus*. The meral joints are armed on the upper and anterior margin with spiniform teeth, as in that species; the tubercles of the upper surface of the last pair are more depressed. The carpal and propodal joints are ornamented with lobate crests, of which there are three on the carpal joints of the first, second, and third pairs, and two on the propodal joints and on the carpal joint of the fourth pair. The middle crest of the carpal joints (the anterior crest in the last pair) is most prominent, and is composed of three rounded lobes, the interspaces as wide as the lobes. Ambulatory legs hairy, the dactyli densely so.

Abdomen of male with the first three segments tuberculous; anterior margin of each segment, including the coalesced segments, marked by a transverse band of pubescence. Posterior half of sternum tuberculous; anterior half punctate or pitted.

*Dimensions*.—Male, type; length, 17 mm.; width, 25.6 mm. Female with eggs, station 2813: length 8.5 mm.; width 12.3 mm."

***Medaeus rugosus*, sp. nov. (Hooded Crab).**

*Diagnostic characters*.—Carapace hexagonal, anterior three-fourths, also upper surface of chelipeds coarsely granulose and very convex.

*Type*.—The type, an ovigerous female, was taken at station 54, Gardner Bay, off Hood Island by Dr. William Beebe, while diving in 15 feet of water, and is deposited in the collections of the New York Zoological Society.

*Galapagos distribution*.—*Arcturus* station 54, off Hood Island (type locality).

*General distribution*.—This species is known only from the Galapagos holotype.

*Technical description*.—Carapace 4.5 mm. long, 6.5 mm. wide, interorbital space 2.5 mm. wide. The frontal border is more than half of the maximum width of the carapace and is a straight line whose margin is ventral in position forming a hood over the antennular fossette; the outer distal margins of the front are rounded dorsally and continuous with the superior orbital border; they are produced on the ventral side meeting the distal inner angle of the basal antennal segment. The superior orbital border is semicircular and unbroken and is continuous with the similar inferior orbital margin. The anterolateral margins are arcuate and granular; there is a faintly indicated angulation at the beginning of the postlateral margins which are sinuous and decidedly converging. The anterior three-fourths of the carapace is covered with round granulations and sparsely with a fine pubescence. This region is very convex, the frontal and gastric areas forming a pair of prominent lobules which are separated from each other by a shallow median depression and are similarly faintly defined on their outer margins by the cervical groove; the hepatic region is not especially tumid but the branchial areas are decidedly inflated and are ornamented with miniature lobules composed of granules. The cardiac region is distinctly defined but rather depressed; there are a pair of depressions, one at each end of the urogastric groove; the intestinal region is clearly defined and

slightly higher than the cardiac region. The surface of the posterior part of the carapace is marked by broken transverse ridges which approximately parallel the posterior margin. The undersides of the carapace are finely granulate and the parts adjacent to the legs are covered with a coarse pubescence. The female abdomen consists of seven segments and is oval with the distal end rounded; the entire margin is set with long thickly plumose setae; the outer rami of the appendages project beyond the abdomen like spokes of a wheel and support the huge egg-mass which is attached to the long, silky hairs of the inner rami.



Fig. 70. *Medæus rugosus*, female, type  $\times 4$ .

The eyestalks are short and but little of them is visible; the cornea is convex, large and shining black.

The antennulae have the basal joint very wide and short, the two free joints are subequal, stout, cylindrical, and fold transversely within the septum; the flagella are short; the larger branch bears a tuft of setae.

The external antennae are rudimentary, minute, reaching only to the base of the cornea.

The external maxillipeds have the ischium subrectangular with the distal margin a little oblique; the merus is about half as long as the ischium and is a little wider than long, the inner distal margin is slightly notched for the reception of the close-fitting three-jointed palp.

The chelipeds are equal in the female; the meral joint is elongate, trigonal, closely appressed to the carapace with only the distal upper edge showing beyond it; the carpus is very large, convex and lumpy on its upper and outer surface; it is as long as the palm of the propodus; both the carpus and propodus have the upper inner margin cristate; the outer surface of the palm is convex, lumpy and granulose. The fingers are subequal, the propodal being a trifle thicker and the upper finger more curved; both fingers are fluted on the outer and upper surfaces, the ridges and also the interspaces being covered with granules; the cutting edges are coarsely dentate and fit closely upon each other.

The four pairs of ambulatories are similar and subequal, decreasing slightly in length from the first to fourth pairs; all have the meral joint long and flattened; the carpal and propodal joints are short, stout, thick and roughened on the upper surface; the dactyl is as long, or a little longer, than the propodus but is much slenderer, cylindrical, and tipped with an acuminate spine.

### Subfamily Actaeinae

#### Genus *Actaea* de Haan, 1883

Key to the Galapagos species of the genus *Actaea*.

Carapace with anterolateral margins evenly rounded, quadri-lobate; finely granulose and coarsely setiferous.

*dovii*

Carapace with anterolateral lobes dentiform; lobulated posteriorly as well as anteriorly.

*angusta*

*Actaea dovii* Stimpson.

*Actaea dovii* Stimpson, *Ann. Lyc. Nat. Hist. N. Y.*, vol. 10, p. 104, 1871; *A. Milne Edwards, Crust. Rég. Mex.*, p. 244, pl. 44, fig. 1, 1880; *Faxon, Mem. Mus. Comp. Zool.*, vol. 18, p. 16, 1895; *Rathbun, Proc. Washington Acad. Sci.*, vol. 5, p. 281, 1902; *Proc. U. S. Nat. Mus.*, vol. 38, p. 583, 1910.

*Name*: Professor Stimpson named this species in honour of Captain J. M. Dow who collected many new and unusual crustaceans on the west coast of America, about 1855 to 1870.

*Diagnostic characters*.—Anterolateral margins evenly rounded, quadri-lobate. Carapace, chelae and ambulatories finely granulose and coarsely setiferous.

*Type*.—Professor Stimpson's type material was collected in San Salvador by Captain Dow and in Panama by Alexander Agassiz and was deposited in the "museum of the Smithsonian Institution." I understand that the type is no longer extant.

*Galapagos distribution*.—Off Hood Island, *Arcturus* station 54, specimens secured by William Beebe, while diving in 15 feet of water. Tagus Cove, Albemarle Island, on reef north of Tagus Hill (Hopkins-Stanford Expedition).

*General distribution*.—Panama; San Salvador; Galapagos archipelago and Ecuador.

*Material examined*.—Eighteen males, four females and six megalops from station 54, off Hood Island, Galapagos, taken by William Beebe, while diving in 15 feet of water. This extensive series does not show the males to be "considerably narrower than the female" as did the material obtained by the Hopkins-Stanford Expedition and examined by Miss Rathbun.

*Color*.—The very young specimens of this species, about 3 to 5 mm. wide, have alternate red and cream white stripes radiating from the central part of the posterior region outward to the frontal and lateral margin. In older specimens, 10 mm. or more wide, the stripes are replaced by solid orange-red coloration.

*Habits*.—This interesting *Actaea* dwells in the crevices of the coral rocks. It feeds on worms, small amphipoda and larval crustaceans.

*Technical description.*—Carapace very convex anteriorly, oval; 9 mm. long, 13 mm. wide; covered with fine close-set granules which are more prominent anteriorly; also set with coarse, stiff, up-standing yellow-brown setae. Inter-orbital space 5 mm. wide; median notch large, V-shaped; frontal edge recurvate, granulate; the superior and inferior orbital margins are granular and unbroken except for the internal orbital hiatus. The frontal region is divided by a median sulcus into two lobes and two more sulci run backward from just inside the preorbital angle defining the outer pair of the four frontal lobes. The antero-lateral border is divided into four lobes which do not project beyond the rounded lateral border; the sulci defining them are distinct but not especially deep. The pterygostomial regions and under sides of the carapace are also finely granulate.



Fig. 71. *Actæa dovii*,  $\times 3$ .

The female abdomen is very narrow, with the distal end tapering and rounded and the entire margin heavily fringed with setae. It is seven-segmented, the sixth and seventh segments each being nearly twice as long as the fifth segment.

The male abdominal belt is five-segmented, segments three, four and five being anchylosed. The first pair of male appendages are well developed rods with the distal end flattened and spinose.

The chelipeds are equal in both sexes. They are covered with coarse granules on the upper and outer surface of the merus, carpus and propodus, with occasionally a few tubercles on the proximal part of the fingers. They have the coxal and basis joints small; the ischium fused distally with the merus; the merus is very stout and produced on its inferior distal margin into a rounded knob; the carpus is moderately rounded on its outer surface and is a trifle longer than the palm of the propodus; the propodus has the hand convex and almost as wide and high as it is long; the fingers are a trifle more than half as long as

the palm and are very strong. The propodal finger is deeply grooved on its outer and under surfaces and bears a strong basal tooth, followed by two more well developed teeth and the acuminate tip; the hinged finger is as large as the propodal but is more curved and bears five teeth on the cutting edge besides the tip; it is also deeply fluted. The fingers fit closely upon each other.

The first three pairs of ambulatory legs are subequal, the fourth pair is similar in structure but much smaller, reaching scarcely to half way the length of the propodus of the third leg. Each leg has the meral, carpal and propodal joints stout, the meral joints being half as wide as long and granulous along the upper edge and the exposed parts of the dorsal surface; the carpus and propodus are each about three-fourths as wide as long and granulose and setigerous; the dactyl is a trifle longer than the propodus and less than half as wide; compressed cylindrical, curved and tapering distally to a sharp, horny point. The dactyli are also granulose and setigerous.

The antennulae are well developed and fold transversely within the fossett.

The external antennae are very small; the basal joint is ankylosed and is produced at the inner distal angle into a sharp point; the next two joints are free, very small and lie within the orbital hiatus; the flagellum is composed of about ten tapering articles and reaches to the cornea.

The external maxillipeds are close-fitting, rectangular. The exognath has a small basal joint and a long, slender second joint which is produced into a tooth-like process on its distal inner angle; the ischium is subrectangular, almost two-thirds as wide as long, with the inner margin fringed with setae; the merus is about half as long as the ischium and has the anterior border oblique; the palp has the basal joint stout, the second and third joints tapering, the latter being heavily fringed with setae.

*Actaea angusta* Rathbun.

*Actaea angusta* Rathbun, *Proc. U. S. Nat. Mus.*, vol. 21, p. 582, pl. 42, fig. 2, 1898.

*Diagnostic characters*.—"Carapace narrow, posteriorly lobulated; lateral lobes dentiform; fingers rough." (Rathbun.)

*Type*.—The type of this species, an immature female, was taken by the steamer *Albatross*, at Station 2812, off Hood Island, Galapagos, in 20 fathoms, and is deposited in the United States National Museum (Cat. No. 21578).

*Galapagos distribution*.—Off Hood Island, *Albatross* station 2812, in 20 fathoms.

*General distribution*.—Known only from the type-locality.

*Material examined*.—Being unable to secure material of this species, I quote Dr. Rathbun's diagnosis of the type.

*Technical description*.—"Carapace narrow, slightly convex, lobulate on the posterior as well as the anterior half; lobules granulous. The posterior half of the mesogastric region is long, and its sides are distinctly convergent backward; the depressions which form its lateral borders are continued posteriorly in divergent lines, thus forming a figure the shape of an hour-glass. On either side of this there is a large branchial lobule, not distinctly limited posteriorly. Front slightly deflexed, its margin visible in a dorsal view; lobes oblique, nearly



straight, separated by a broad V-shaped notch. Lateral lobes four, besides the orbital, dentiform, the first very short, the second twice as long, the third much the longest. Inner suborbital lobe rounded, prominent."

"Chelipeds covered with spiniform tubercles, the carpus deeply grooved, the tubercles on the hands arranged in longitudinal rows. Fingers deeply

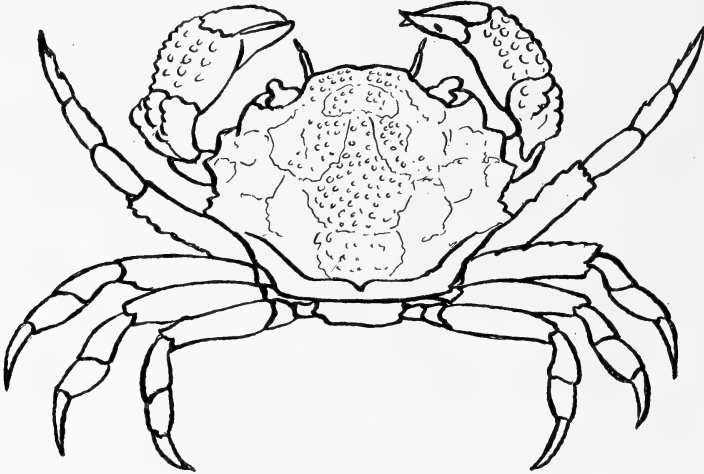


Fig. 72. *Actæa angusta*,  $\times$  about 4 (After Rathbun).

grooved, the intervening ridges rough with spiniform tubercles. Ambulatory legs granulate."

This species resembles *Actæa setigera* (Milne Edwards) and *Actæa dovii* Stimpson in the ornamentation of the carapace and in the chelipeds; it differs from them in being narrower and posteriorly areolated, and having dentiform lateral lobes. It resembles *Actæa bifrons* Rathbun in its proportions and lateral lobes, and differs in its front, posterior areolations and roughened and grooved fingers."

#### Genus *Platypodia* Bell

*Platypodia gemmata* Rathbun (Galapagos Jewelled Crab).

*Platypodia gemmata* Rathbun, *Proc. Wash. Acad. Sci.*, vol. 4, no. 8, p. 279, pl. 12, figs. 5 and 6, 1902; *Proc. U. S. Nat. Mus.*, vol. 38, p. 584, 1910.

**Diagnostic characters.**—Frontal edge thin, slightly bilobed; anterolateral margins quadrilobate. Anterior two-thirds of carapace divided into about twenty lobules.

**Type.**—The type, an ovigerous female, and three additional specimens were taken on a reef north of Tagus Cove, Albemarle Island, by the Hopkins-Stanford Galapagos Expedition and are deposited in the United States National Museum (Cat. No. 24850).

**Galapagos distribution.**—Known only from the type-locality.

**Material examined.**—None. I have not been able to secure this species for examination.

*Technical description.*—The following is the original description of the type: "Anterior two-thirds of the carapace divided into about twenty lobules, for the most part circular, except the mesogastric lobule; covered with crowded depressed granules and separated from each other by depressions, filled with a dense furry coating. The front has a thin bilobed edge, the lobes slightly sinuous. The antero-lateral margin is thin and covered above by a short fringe

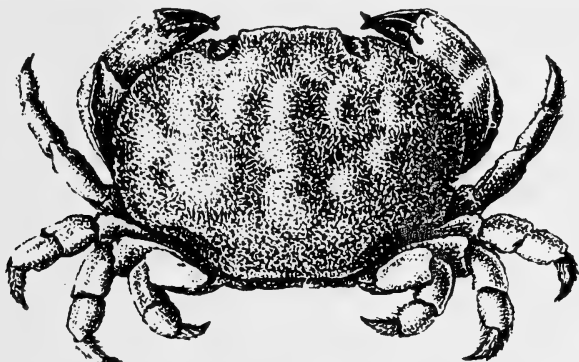


Fig. 73. *Platypodia gemmata*,  $\times$  about 6 (After Rathbun).

of fur; below, there are three fissures visible, dividing the margin obscurely into four lobes. The posterolateral borders are short and deeply cut.

The upper border of the merus, carpus and propodus of the chelipeds and ambulatory legs is sharply cristate. The chelipeds are granulated on the outer surface, the granules larger than on the carapace and arranged on the lower half of the hand in four longitudinal rows. The ambulatory legs are partially granulate. *Dimensions:* Ovigerous female, length 6.8 mm., width 9.6, fronto-orbital width 4.9, width of front 2.8."

#### Subfamily: CHLORODIELLINAE

Genus *Xanthias* Rathbun, 1852

Key to the Galapagos species of the genus *Xanthias*.

Black tip of fixed finger of chelae produced backward on propodus almost to basal joint; carpus and propodus and anterior region of carapace uniquely nodulose.

*insculpta*

Brown tip of fingers not produced backward on propodus; carpus, propodus and anterior region of carapace roughly granular.

*politus*

*Xanthias insculpta* (Stimpson), 1871. (Sculptured Crab; Volcanic Pebble.)

*Xanthodes insculpta* (Stimpson), *Ann. Lyc. Nat. Hist. N. Y.*, vol. 10, p. 105, 1871.

*Xanthias insculptus* Rathbun, *Bull. Lab. Nat. Hist. State Univ. Iowa*, vol. 4, p. 271, 1898.

*Xanthias insculpta* Rathbun, *Zoologica*, N. Y. Zool. Soc., vol. 5, p. 157, fig. 38, 1924.

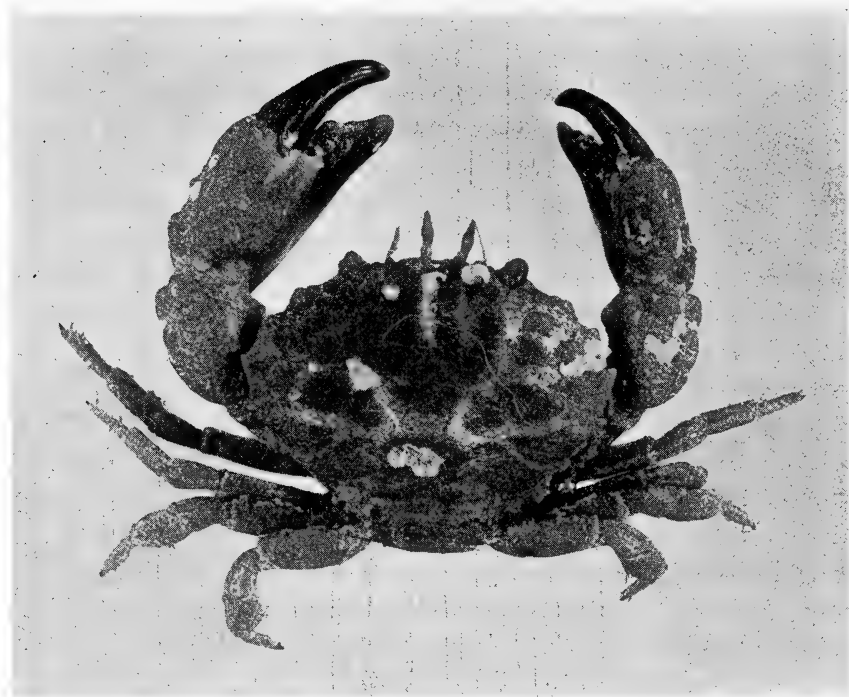


Fig. 74A. *Xanthias insculpta*,  $\times 3.2$ .

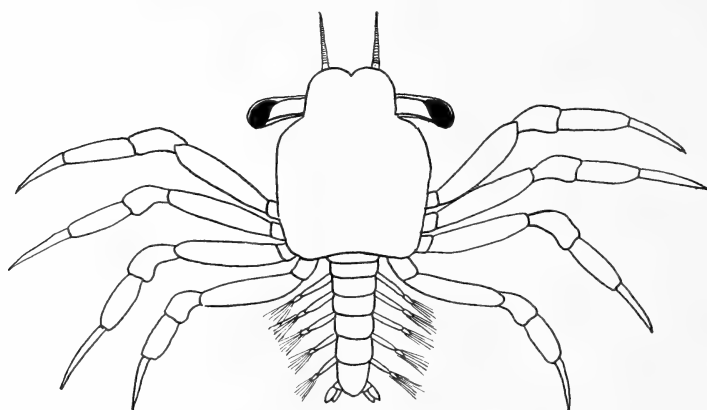


Fig. 74B. *Xanthias insculpta*, megalops,  $\times 20$ .

*Diagnostic characters.*—Black tip of fixed finger of chelae produced backward on propodus almost to basal joint; carpus and propodus uniquely nodulose; anterior region of carapace similarly rugose and nodulose.

*Type.*—The specimen on which Stimpson founded this species was taken at Cape St. Lucas, Lower California and is unfortunately no longer extant.

*Galapagos distribution.*—Eden Island, five fathoms, (Harrison Williams Expedition); *Arcturus* station 54, off Hood Island, 15 feet.

*General distribution.*—This species was known only from the type-locality, Cape St. Lucas, Lower California, where it was taken in 1871, until the Harrison Williams Galapagos Expedition, 1923, when an immature male and one other young specimen were secured off Eden Island, in five fathoms of water, by William Beebe.

*Material examined.*—No better illustration of the marvelous advantages a collector may secure by the use of a diving helmet could be desired than the splendid series of elf-like crabs and megalops representing this species obtained by William Beebe, diving in fifteen feet of water at Station 54, off Hood Island. One megalops, 42 males, 30 ovigerous females, 24 females not ovigerous mostly young specimens, were secured, ranging in size from the miniature megalops figured (74B) through a series of minute ovigerous females and males to the seeming great-great-grandfather of the species, (Fig. 74A).

*Technical description.*—Carapace 12 mm. greatest length; 14 mm. greatest width; interorbital margin broad, produced into two lobed teeth separated by a V-shaped sinus, which is produced posteriorly on the gastric region in the form of a median sulcus; a lesser notch at the outer margin of the median tooth is similarly produced separating the inner orbital lobe from the median; the anterolateral margin is broken by four subequal and subequally spaced teeth; the most anteriorly placed tooth is the largest and while pointed is less incurved on its anterior margin, the second and third teeth are equal and are decidedly forward-directed, the fourth tooth is situated at the terminatoin of the carination with traverses the carapace and is outward-directed. The frontal and gastric regions are deeply nodulose; the upper outer half of the carpus and wrist are similarly nodulose. There is a less distinct transverse row of nodules ruoghly paralleling the posterior sulcus and a less distinct sulcus brokenly traversing the carapace and terminating in the third lateral tooth. The postlateral margins are sharply convergent; the posterior margin is produced into a ridge-like thickening. The male abdomen is five-jointed. The female abdomen is ovate, seven-jointed and fringed marginally with long golden hairs. In ovigerous females the abdomen is expanded behind the carapace and the pleopoda of the third, fourth and fifth segments are long, slender, biramose; the outer rami are projected like rays of a fan from the side of the abdomen; the inner rami are projected ventrally at an oblique angle; both rami are rod-like and heavily fringed with long setae; the inner rami and hairs form the central stem for the grape-like clusters of eggs. A single female 7 mm. wide, 5.5 mm. long carried 742 eggs.

Mr. Beebe, when diving, collected lumps of coral rock in a bucket and later these little crabs were picked out of the small crevices into which they fitted snugly, facing the entrance which was well guarded by their huge-Lilliputian

chela. It is understandable that thus guarded the unusually exposed egg-clusters escape their myriad enemies. The eggs are encased in a transparent membrane through which the minute old ivory tinted embryos with blackish grey eyes may be seen. The eggs taken average a diameter equal to one-fourth of that of the cornea of the adult.

The basal antennal joint is very short and broad, the flagellum, situated in the orbital hiatus, is somewhat longer than the orbit.

The eyes are well-developed, translucent, golden-brown in color.

The chelipeds are massive, the left is slightly larger than the right; when closed, only the distal part of the merus is seen in a dorsal view, the proximal part of the leg being hidden under the body. The carpus is very convex dorsally, much dilated distally; the left hand continues the characters of the carpus but is even more dilated; it is laterally compressed, outwardly convex; the lower half smooth; the approximate center traversed by a longitudinal carination which terminates at the inner angle of the fixed finger; the upper half of the carpus is nodulose. The fixed finger is very broad basally, triangulate, and bears a strong molar tooth near the base of the inner margin and two lesser teeth near the apex. The movable finger is slender, strongly curved, the fingers meet apically, but there is a wide gape even when closed. The ambulatory legs are short, subequal; have the meral, carpal and propodal joints flattened, lamellar, and the dactyl slender, lance-like.

*Xanthias politus* (Rathbun).

*Micropanope polita* Rathbun, *Proc. U. S. Nat. Mus.*, vol. 16, p. 238, 1893.  
*Panopeus tanneri* Faxon, *Bull. Mus. Comp. Zool.*, vol. 24, p. 154, 1893;  
*Mem. Mus. Comp. Zool.*, vol. 18, p. 19, pl. 3, fig. 4, 4a, 1895.  
*Xanthias politus* Rathbun, *Bull. Labr. Nat. Hist. State Univ. Iowa*, vol. 4, p. 271, 1898; *Proc. U. S. Nat. Mus.*, vol. 21, p. 587, 1898; *Proc. Washington Acad. Sci.*, vol. 4, p. 281, 1902.

*Diagnostic characters*.—Front broad, median notch narrow, lobes nearly straight. Five anterolateral teeth. Anterior margin of merus of external maxillipeds sinuous.

*Type*.—The type of this species was taken off Magdalena Bay, Lower California, lat. 24°, 58', 15" N., long. 115°, 53' W., 36 fathoms, station 2889, U. S. Fish Commission Steamer *Albatross*, and is deposited in the United States National Museum.

*Galapagos distribution*.—Hood Island, 20 fathoms; Tagus Cove, Albemarle Island, 12 fathoms; off Galapagos Islands, 53 fathoms.

*General distribution*.—Lower California, 31 to 36 fathoms; near Cocos Island, 66 fathoms, Galapagos Islands, 12 to 53 fathoms.

*Material examined*.—None.

*Technical description*.—The following is Miss Rathbun's description of the type: "Carapace transverse, convex longitudinally, smooth and punctate posteriorly, rough-granulate anteriorly, the granules most prominent on the hepatic regions. Front broad, median notch narrow, lobes nearly straight, thin, denticulate. Areolations distinct. Antero-lateral teeth five (with the orbital angle); a concave sinus between the first and second; last tooth similar in character to the others, but smaller. Inferior regions of the carapace and surface of maxillipeds granulate. Sternum and abdomen smooth and punctate. Ab-

domen of male with five segments, the first and second broad, the second narrowest at its distal end. Basal antennal joint reaching the front. Anterior margin of merus of outer maxillipeds sinuous. Large cheliped, with merus

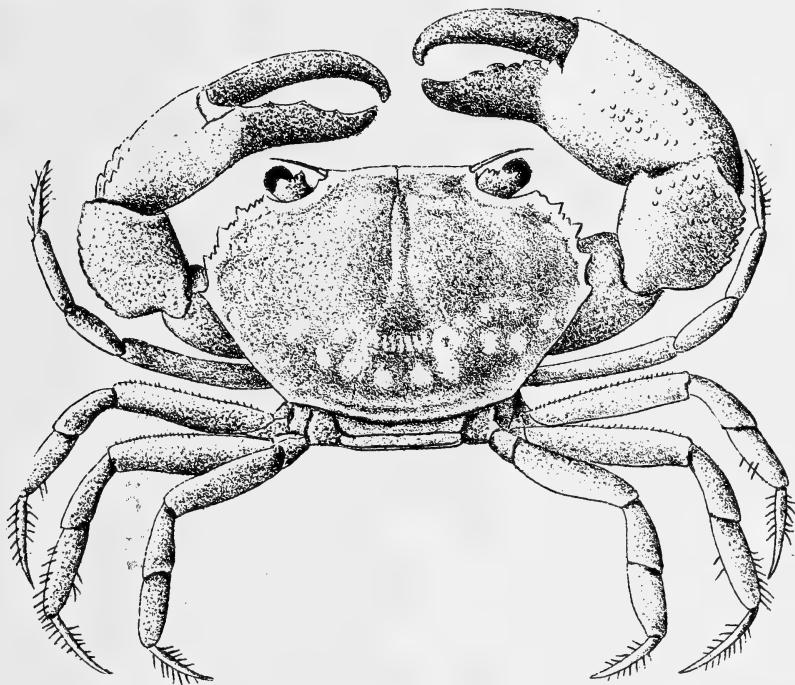


Fig. 75. *Xanthias politus*,  $\times$  about 4 (After Faxon).

finely granulate, dentate on the upper margin; carpus with spiny granules arranged in indistinct transverse ridges, an acute spine inside; hand granulate above and near the carpus, smooth and punctate elsewhere; palm broad, convex on lower margin; fingers brown, with lighter tips. The small cheliped differs in its much narrower, more granulate hand, with almost straight lower margin. Ambulatory legs slender, punctate, spinulose above, last three joints hairy.

Length of carapace 6.2, width 9.8 millimeters."

#### Subfamily: PANOPEINAE

#### Genus *Eurypanopeus* A. Milne-Edwards

#### *Eurypanopeus transversus* (Stimpson).

*Panopeus transversus* Stimpson, Ann. Lyc. Nat. Hist. N. Y. vol. 7, p. 210, 1860.—Benedict and Rathbun, Proc. U. S. Nat. Mus. vol. 14, p. 367, pl. 22, fig. 2, pl. 24, fig. 9, 1891.

*Eurypanopeus transversus* Rathbun, Proc. U. S. Nat. Mus. vol. 38, p. 543, fig. 2, 1910.

*Diagnostic characters*.—A small *Panopeus* with the anterior half of the cara-

pace decidedly convex, the posterior half rather flattish; anterolateral margin cut into five lobate teeth. The coxal joint of the fifth legs are in contact with the third abdominal segment.

*Type*.—Prof. Stimpson's type material came from West Mexico.

*Galapagos distribution*.—One male specimen taken at Conway Bay, Indefatigable Island, Galapagos, April, 1923, by the Harrison Williams Galapagos Expedition appears to be the first Galapagan record for this species.

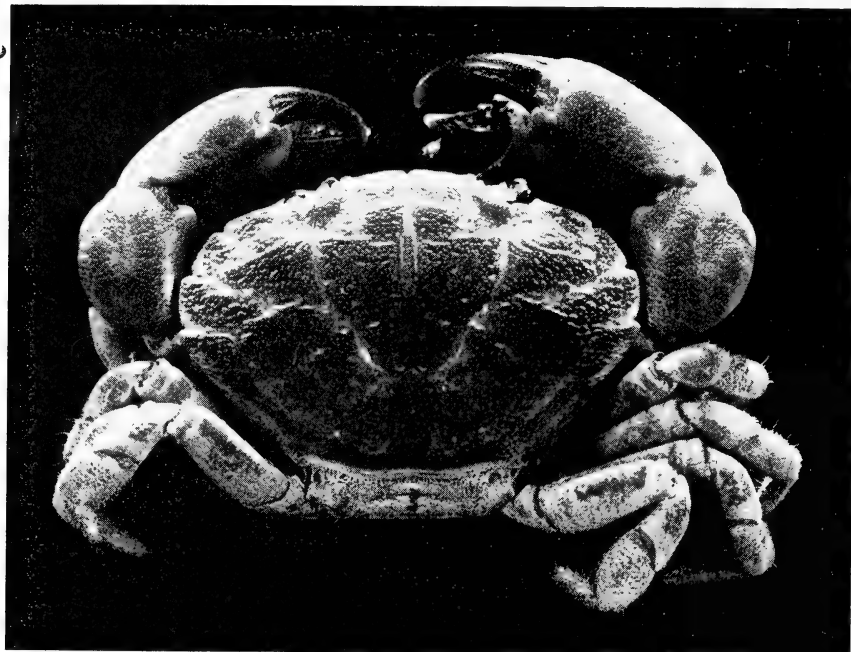


Fig. 76. *Eurypanopeus transversus*,  $\times 3$ .

*General distribution*.—Acajutla, San Salvador (Yale Museum); Las Vacas, near Capon, Peru (U. S. National Museum); Galapagos Islands (*Noma* Expedition).

*Technical description*.—Carapace 20 mm. wide, 12.7 mm. long, broadly oval, with the anterior half decidedly convex, curving downward to the frontal margin; the posterior half flattish; areolations clearly defined but not especially raised. The interorbital region equals about one-third of the width of the carapace and is divided by a small median notch, and a pair, one each near the outer angle. The anterolateral margin is broadly rounded with the first and second teeth completely fused, forming a blunt lobe; the third and fourth are subequal, truncated, separated by a slight V-shaped incision from the apex of which a brief groove runs inward; the fifth tooth is dentiform and con-

tinuous posteriorly with the converging postlateral margins. The abdomen is seven segmented; the third abdominal segment is in contact with the coxal joint of the fifth pair of legs.

The eyestalk is short; the cornea is large but not dilated.

The antennulae are stout and fold within the septum.

The antennae have the peduncular joints situated in the orbital hiatus, and a short multiarticulate flagellum.

The chelipeds are distinctly unequal; the proximal joints are strong, the merus is rather massive; the carpus is long, with the upper and outer surfaces rounded, a blunt tooth at the inner angle; the propodus is evenly rounded, well developed the dactyli are slender, subequal; the lower finger has a large basal tooth in the male.

The ambulatories are rather narrower for a *Eurypanopeus*.

#### Genus *Eurytium* Stimpson, 1859

*Eurytium affine* (Streets and Kingsley) 1877.

*Panopeus affinis* Streets and Kingsley, *Bull. Essex. Inst.*, vol. 9, p. 106, 1877.  
*Eurytium affine* A. Milne Edwards, *Crust. Rég. Mexic.*, p. 334, pl. 60,  
 fig. 1, 1880; Rathbun, *Proc. U. S. Nat. Mus.*, vol. 38, p. 585, 1910.

*aine* /

*Diagnostic characters*.—Carapace but little convex; four anterolateral teeth besides the postorbital tooth; these are distinctly separated—the first and second being broad and blunt, the third and fourth raised and angled.

*Type*.—The type specimen came from Lower California and is probably deposited in California Academy of Science collections.

*Galapagos distribution*.—One male specimen of this species, taken at Conway Bay, Indefatigable Island, by the Harrison Williams Galapagos Expedition, established the first Galapagan record for this rare species, hitherto known only from Lower California.

*General distribution*.—Lower California (type-locality) and Galapagos Islands. Dr. Rathbun cites Ecuador as a doubtful record of this species, without explanation of the source of her information.

*Material examined*.—One male specimen from Conway Bay, Indefatigable Island, secured by the Harrison Williams Galapagos Expedition.

*Technical description*.—Carapace 15 mm. long, 20 mm. maximum width; interorbital space 7 mm. wide. The carapace is only a little convex from the front to back and has the regions clearly delineated; these defining grooves being heavier on the posterior regions. The frontal border is a little more than one-third the maximum width of the carapace and has the frontal margin straight, granulose, divided into two lobes by a slight median fissure from which a median groove runs backward on the carapace and bifurcates, defining the cardiac region. The outer angles of the frontal lobes are right-angled. The superior orbital margin is slightly raised and granular, and defined by an obtuse post-orbital tooth which is separated from the first marginal tooth by a shallow curve. The anterolateral margins are cut into four teeth, in addition to the postorbital tooth. The first tooth is obtuse and but little more than half as wide as the second tooth; the second tooth is broad and blunt with a slight point near its anterior angle; the third tooth is about as wide as the second but



is more raised, and has a median rib of granules on its inner surface, giving it a triangular aspect; the fourth is the smallest of the series and is also raised and has a median rib of granules running inward from its apex. Behind this fourth tooth the posterior margins converge abruptly. The branchial regions are slightly tumid. In addition to grooves delineating the regions of the carapace, there are many fine low granules especially on the anterior region of the carapace. Some of these form irregular, broken, transverse lines on the gastric and branchial regions. The undersides of the carapace are slightly pubescent and granular.

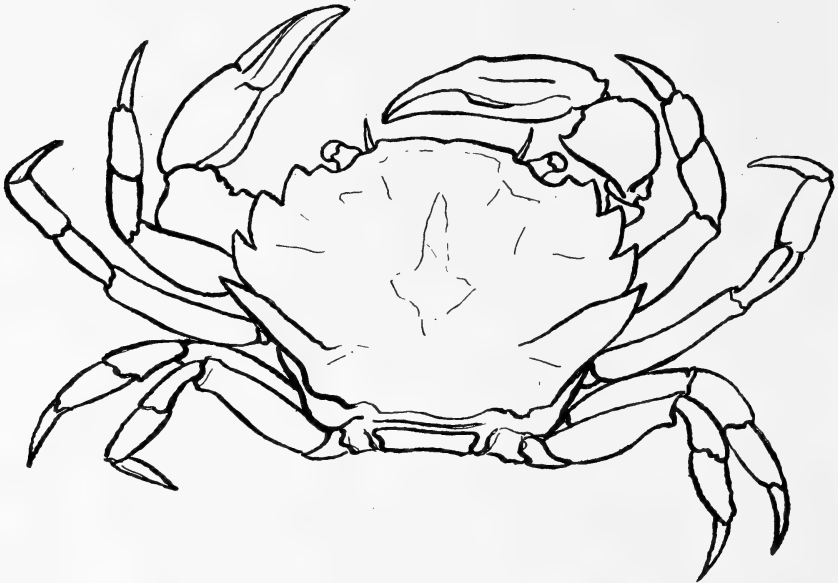


Fig. 77. *Eurytium affine*,  $\times 2.5$ .

The eyestalk is short, decidedly constricted below the cornea and produced on the upper surface into a small, rounded process that projects upon the cornea; the cornea is spherical and is composed of many very minute hexagonal facets.

The antennulae are well developed and fold transversely within the septum.

The external antennae have the basal article lodged at the outer end of the antennulae, in the orbital hiatus; the second joint is small, compressed, sub-cylindrical, the third joint is only about half as long as the second; the flagellum consists of about 25 annulations and extends to the anterior margin of the first lateral tooth.

The external maxillipeds have the second joint of the exognath long, rectangular; the ischium is subrectangular with the inner margins rounded basally, the outer face is channelled longitudinally and has this line set with coarse setae; the merus is about three-fifths as long as the ischium and has its outer distal

border produced and rounded, its inner distal border notched and its outer surface irregularly channelled, granulated and covered with bristly setae; the three-jointed palp is stout, tapering, subcylindrical.

The chelipeds are unequal in the male; they have the meral joint stocky, trigonal, with the inner surface flattened and closely appressed to the sides of the carapace; the carpus is rounded on the upper and outer surfaces and finely granular; there is a triangulate tooth on the inner subdistal margin; the propodus is one-half as long as the maximum width of the carapace, the fingers comprising about two-fifths of this length; the propodus is three-fourths as high as it is long, with the outer and upper surfaces convex and the inner surface concave on its proximal part; all three surfaces are finely granular; the fingers are short, stout, weakly channelled by shallow, longitudinal grooves, and with a gap between them. The hinged finger bears a large, blunt, basal tooth. The fingers of the small chela lack this large basal tooth and they do not gape.

The four pairs of ambulatories are similar and slightly decrease in length from the first to fourth pairs, in the order named. All are long and slender and have the meral joint very long and compressed laterally, the carpus and propodus are approximately subequal and taken together are as long as the merus. The dactyl is almost straight, very slender, tapering and acuminate; the sides of the dactyl and the distal under part of the propodus are covered with stiff, bristly setae.

#### Subfamily: MENIPPINAE

#### Genus *Pilumnoides* Milne Edwards and Lucas

#### *Pilumnoides pusillus* Rathbun.

*Pilumnoides pusillus* Rathbun, *Proc. Washington Acad. Sci.*, vol. 4, p. 281, pl. 12, figs. 9, and 10, 1902; *Proc. U. S. Nat. Mus.*, vol. 38, p. 585, 1910.

*Diagnostic characters.*—Anterolateral margin four-toothed; anterior region of carapace lobulated; upper surface of carpus and propodus of chelipeds lobulated. Chelae unequal.

*Type.*—This species was founded on two male specimens taken at Tagus Cove, Albemarle Island, on reef north of Tagus Hill, March 16, 1899, by the Hopkins-Stanford Galapagos Expedition and which are deposited in the United States National Museum.

*Galapagos distribution.*—Tagus Cove, Albemarle Island (type-locality) and *Arcturus* station 54, off Hood Island, in 15 feet of water.

*General distribution.*—Known only from the Galapagos Archipelago.

*Material examined.*—Five male specimens and one female taken at *Arcturus* station 54, off Hood Island, Galapagos Island by William Beebe, while diving in 15 feet of water.

*Technical description.*—Carapace 4 mm. long, 6 mm. wide, moderately convex anteriorly and distinctly lobulate; the frontal region is divided by a median longitudinal sulcus into two prominent lobules and there are four prominent and one feeble lobules on the anterior region adjacent to the anterolateral margin, one lobule being postorbital in position and each of the other four being inside of the respective anterolateral teeth; occasionally the feeble lobe, which is adjacent to the last tooth, is obsolete. The entire surface of the

carapace and the outer and upper surfaces of the chelipeds and ambulatories are finely granulate. The interorbital border is 1.7 mm. wide, slightly sinuate, with the outer angles forming an obtuse tooth. The superior orbital border is sinuate and is marked by two lines indicating closed fissures. The postorbital tooth is small. The anterolateral border is broken into four distinct, triangular tuberculiform teeth; the first, second and third teeth are subequal, the fourth tooth is smaller but very acuminate; a transverse beading runs inward from



Fig. 78. *Pilumnoides pusillus*,  $\times 9.5$ .

the fourth tooth upon the carapace. The postlateral margins are convergent. The pterygostomian region and under sides of the carapace are finely granular.

The antennulae are well developed, and fold almost transversely within the fossette beneath the frontal lobes.

The external antennae have the basal segment almost reaching the inferior orbital margin; the first free segment small, rectangular, situated in the orbital hiatus, the flagellum long, composed of eight, long, slender articles.

The external maxillipeds have the second joint of the exognath a long, narrow rectangle, reaching to the distal border of the merus; the ischium is rectangular, about two-thirds as wide as long; the merus is a little more than half as long as the ischium and has the inner margin somewhat rounded; the palp consists of three stout, tapering articles.

The chelipeds are moderately unequal in both sexes. The merus is well-developed yet is scarcely visible in a dorsal view. The carpus and propodus are greatly developed and project beyond the carapace conspicuously. Both are lobulated on the upper and outer surfaces; the propodal finger is stout, strongly toothed on the cutting edge and marked by two carinae, the lower one of which runs backward on the palm. The hinged finger has a deep groove on the upper surface and is decidedly curved and distinctly toothed. When closed, the fingers of the large chela have a small basal gap; those of the small chela vary, being sometimes close-fitting and occasionally with a hiatus.

The four pairs of ambulatory legs are small, similar; the first three pairs are subequal; the fourth pair is much shorter. Each has the meral, carpal and propodal joints broad, the dactylus long, slender and but little curved, except at the horny tip. All the legs are sparsely set with long hairs.

### Subfamily: PILUMNINAE

Genus *Pilumnus* Leach, 1815

Key to the Galapagos species of the genus *Pilumnus*.

- |  |                   |
|--|-------------------|
| Anterolateral margin four-toothed including the postorbital, each of which is serrated by fine spinules.   | <i>spinulifer</i> |
| Anterolateral margin five-toothed, including the postorbital; carapace distinctly areolated, anterior region rough with broken transverse rugae of beadlike tubercles.   | <i>beebei</i>     |
| Anterolateral margin obtuse and rounded, broken into four coalesced teeth. Anterior region of carapace and chelipeds covered with rounded tubercles and densely hirsute. | <i>pygmaeus</i>   |

*Pilumnus spinulifer* Rathbun.

*Pilumnus spinulifer* Rathbun, *Proc. U. S. Nat. Mus.*, vol. 21, p. 585, pl. 42, figs. 6-8, 1898; *Proc. Washington Acad. Sci.*, vol. 4, p. 281, 1902; *Proc. U. S. Nat. Mus.*, vol. 38, p. 585, 1910.

*Diagnostic characters*.—Chelae unequal, large one with palm diagonally half smooth, small chela with entire surface rough. Carapace distinctly areolated, anterior region quite rough. Anterolateral margin four-toothed.

*Type*.—This species was founded on two male specimens taken by the Albatross off Cape St. Lucas, Lower California, at station 2829, in 31 fathoms. They are deposited in the United States National Museum.

*Galapagos distribution*.—Off Hood Island, at *Arcturus* station 54, depth fifteen feet, four specimens taken by William Beebe; also taken at Tagus Cove, and on a reef north of Tagus Hill, Albemarle Island, by the Hopkins-Stanford Galapagos Expedition.

*General distribution*.—Off Cape St. Lucas, Lower California and Galapagos; in depths ranging from on reef to fifteen feet, also at twelve and thirty-one fathoms.

*Material examined*.—Two females and two male specimens, taken at *Arcturus* station 54, off Hood Island, by Dr. Beebe, while diving in 15 feet of water.

*Technical description.*—Carapace 4 mm. long, 5 mm. wide; interorbital region 2 mm. wide, convex; regions deeply delineated, surface covered thinly with fine setae and short spinular granules which are more abundant on the anterior region, and which are larger and developed into spinules along the anterolateral margin. The frontal border is two-fifths of the maximum width of the carapace and is divided in the middle by a prominent wide V-shaped sinus; the margin is thin and granular, the outer angles of the frontal lobes are rectangular. The superior orbital margin is coarsely granulous or spinulous;



Fig. 79. *Pilumnus spinulifer*,  $\times 9.5$ .

the inferior orbital margin is set with slender spines; the inner suborbital tooth is very prominent, spinulous and acute. The anterolateral margin is armed with four spines including the postorbital, each of which is serrated by fine spinules; the first and second teeth are separated from each other by a wider curve than exists between any of the remaining teeth. Below and between the first and second teeth there is a subhepatic tooth which is smaller than the marginal teeth. The under sides of the carapace are covered with tough spiny granules similar to the upper surface.

The inner antennae are very large and fold transversely within the septum.

The external antennae rather small but support a slender flagellum which is about three-fourths as long as the interorbital border.

The eyestalk is stout, cylindrical, a little swollen and produced on the

upper surface into a short rounded tongue-like process which projects on the cornea.

The external maxillipeds have the exognath well-developed; the ischium is rectangular with the lower part of the inner margin a little rounded; the merus has the distal margin oblique and the inner distal angle notched; the three-jointed palp is well-developed.

The chelipeds are conspicuously unequal in both sexes; the proximal three joints are small, the merus is trigonal, granular on the outer surface, these granules developing into spinules along the margins, those of the upper surface increase in size distally; the carpus is large, convex and very spinous; the propodus of the large chela is large, high and swollen, being three-fourths as long as the maximum width of the carapace; the fingers comprise four-fifths of this length; a little of the upper inner surface, the dorsal surface and the upper basal half of the outer surface of the palm are covered with spinose granules which in most, but not all, specimens become more regularly placed and more granular on the lower and distal regions. The palm of the small cheliped is entirely covered on the outer surface by spinules arranged in longitudinal rows; there are two such rows on the upper surface and the inner surface is very granulose except near the fingers. The basal finger of the large cheliped is stout, marked by two longitudinal grooves on the outer surface and furnished with a large sub-basal and four smaller teeth; the hinged finger is slenderer, more curved and has one very large basal tooth and several small teeth; it is rough with spinules on the upper basal part. The fingers of the small chela are more heavily fluted and frequently more roughened with spinules.

The ambulatories are similar, subequal in length and sparsely setigerous. The meral joints are furnished on the anterior margin with a row of slender spines; their posterior margins are set with spinulose granules; the carpal and propodal joints are armed on the upper, lower and distal margins with spines, the dactyli are slender, acuminate, and spinous on the upper distal margin.

*Pilumnus beebei*, sp. nov.

*Name:* I take pleasure in naming this species in honour of William Beebe, Director of the Arcturus Oceanographic Expedition, whose indefatigable industry in collecting material secured at station 54 within a radius of a few square yards forty-six of the sixty-nine known species of Brachyurans of the littoral crustacean fauna of the Galapagos and further increased this fauna by the addition of nine species, hitherto known only from the West American coast and by five new species of crabs.

*Diagnostic characters.*—Carapace distinctly areolated; anterior region rough with broken transverse rugae of bead-like tubercles. Anterolateral margins five-toothed counting the postorbital as the first of the series. Chelipeds unequal, large one with palm diagonally half smooth; small chela with the entire surface rough with granules.

*Type.*—Seven specimens, three females and four males were taken at Station 54, off Hood Island, Galapagos, by William Beebe while diving in 15 feet of water.

*Galapagos distribution.*—Off Hood Island, in 15 feet of water, *Arcturus* station 54, type-locality.

*General distribution.*—Known only from the Galapagan type-locality.

*Material examined.*—Three females and four males from off Hood Island, Galapagos, station 54.

*Technical description.*—Carapace 5 mm. long, 7 mm. maximum width, deeply areolated, moderately convex, dorsal surface covered with irregular, acuminate granules and fine sparse pubescence. The granules are coarser and

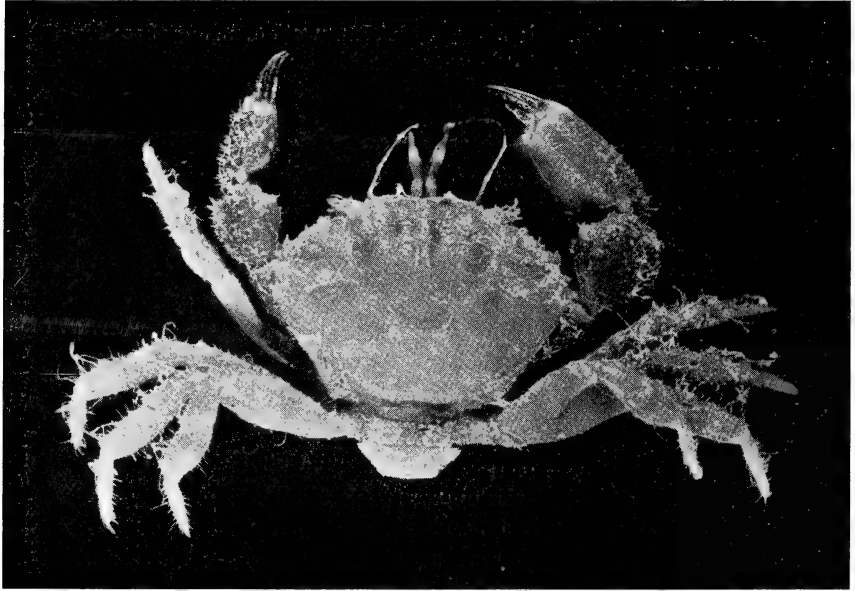


Fig. 80. *Pilumnus beebei*,  $\times 6$ .

more acuminate on the anterior part of the carapace, tending to a bead-like serrate formation along the anterolateral margins; on the posterior region they are finer but very abundant. The interorbital space is 2 mm. wide, with the margin straight, thin and granulate with the outer angles rectangular; the median notch is conspicuous, V-shaped; a shallow sulcus runs inward from it onto the gastric region, defining the two large frontal lobes. The superior and inferior orbital margins are coarsely granulous. The inner, inferior orbital tooth is sharp. The pterygostomian regions and under sides of the carapace are granulous, similar to the dorsal surface of the carapace. The anterolateral margin is quinquedentate, counting the small postorbital tooth as the first tooth. The space between the first and second teeth is greater than that between any of the succeeding teeth; a small, acuminate subhepatic spinule from below the margin is visible dorsally, situated about midway between the first and second

spines. The second spine is usually triangulate, obtuse and subequal to the third spine from which it is separated by a short V-shaped sinus; the fourth tooth is more acuminate than the third and is separated from it by a deeper serration than that between the second and third teeth; the fifth tooth is also acuminate, but is smaller than any of the preceding teeth. The posterolateral margins are convergent.

The male abdomen is triangulate, narrow, five-segmented, the third segment being composed of three coalesced segments. The female abdomen is seven-segmented and narrowly oval.

The chelipeds are conspicuously unequal in both sexes. But little of the meral joint is visible dorsally; this, the distal end, is covered with granules; the carpus is about three-fourths as long as the palm of the propodus and has its upper distal border triangular and finely serrate by coarse granules; the upper and outer surface is also rough with granules; the propodus is four-fifths as long as the carapace is wide, the palm being three-fifths of this length and the fingers comprising the remaining two-fifths. The propodus is thick and is approximately half as high as long with the outer surface convex; the upper surface and the upper half of the outer side are covered with large granules which decrease in size as they approach the lower margin, the lower half or occasionally lower third to fourth being smooth; the fingers are well-developed, brown, the lower one being the thicker and armed with three teeth; the upper finger is more curved and devoid of teeth. Both fingers are fluted by a series of longitudinal carinae and each has a few sharp tubercles usually forming a longitudinal row on the proximal portion. There is a groove-like depression on the upper surface of the propodus which is accentuated by the line-like arrangement of the tubercles. The propodus of the small cheliped is like the large one except that it is more coarsely granulose, the grooves are deeper, and the entire outer surface is covered with acuminate granules.

The first three pairs of ambulatory legs are approximately subequal, the fourth pair is similar but noticeably shorter. All are covered with long setae and have a very few granules on the upper marginal surfaces of the meral, carpal and propodal joints, the dactyli are approximately as long as the propodi and are but little curved except at the horny tip.

The antennulae are quite robust and fold transversely in the fossette, under the frontal margin.

The external antennae are quite small and have the basal joint short, not quite touching the front, the second and third joints slender and situated in the orbital hiatus, the flagellum is composed of about twenty tapering joints and is quite long.

The external maxilliped is rectangular and the ischium has its distal margin a little oblique; the merus is a little more than half as long as the ischium and has its distal border almost transverse; the palp is three-jointed, the basal joint being very well-developed.

*Pilumnus pygmaeus* sp. nov. (Pygmy Crab).

*Diagnostic characters*.—Anterolateral margin arcuate with four obtuse teeth faintly delineated. Anterior two-thirds of carapace and chelipeds covered



with rounded granules and dense pubescence. Palms of both chelipeds with entire outer surface granulose.

*Type*.—The type, an adult female, three ovigerous females, six females, one megalops, and four males were taken at *Arcturus* station 54, off Hood Island, 15 feet, and are deposited in the New York Zoological Society collections.

*Galapagos distribution*.—*Arcturus* station 54, off Hood Island, 15 feet, and Tower Island, shore zone, station 37.

*General distribution*.—Galapagos Islands.

*Material examined*.—Ten females, three of which are ovigerous, one megalops and four males, taken at station 54, by Dr. Beebe while diving in 15 feet of water; also three males and six females from station 37, shore zone, Tower Island.

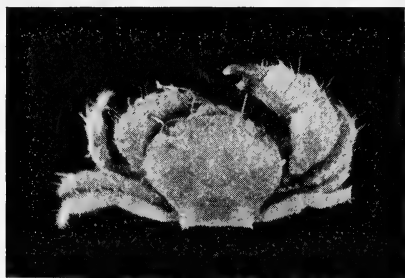


Fig. 81. *Pilumnus pygmaeus*,  $\times 6$ .

*Technical description*.—Carapace 2.8 mm. long, 3 mm. wide; interorbital space 1.5 mm. wide; moderately convex in both directions; interorbital space one-half of the maximum width of carapace; frontal border straight, granulose, with a distinct median notch; superior orbital border semi-elliptical, finely granulose, as is also the inferior orbital margin; anterolateral margin arcuate, broken into four broad, obtuse teeth, which do not, or scarcely, extend beyond the marginal line; anterior two-thirds of carapace covered with prominent rounded tubercles, which are more abundant near the margins; also with a thick pubescence. The undersides of the carapace are also granulose; hirsute. The female abdomen is oval, seven-segmented, fringed with setae; the outer rami of the appendages are extended spoke-like beyond the belt to help support the egg-mass which is attached to the long setae of the inner rami. The male abdomen is five-segmented, triangular; the first pair of male appendages are substantial rods, tapering to an acuminate point.

The chelipeds are conspicuously unequal in both sexes; the merus is trigonal and closely appressed to the carapace, only the upper distal surface showing dorsally; the carpus is very large, convex, approximately three-fourths as long as the palm; the palm is high, very convex on the outer surface; the distal end of the merus, the carpus and the propodus are densely covered with rounded granules and with a thick, long, furry, curved spinose setae. These granules cover the entire upper and outer surface of both palms and are frequently visible

on the proximal parts of the fingers. The fingers are stout, fluted externally, cutting edges dentate and close-fitting.

The four pairs of ambulatories are similar, densely hirsute, the meral, carpal and propodal joints are flattened and the dactyl long, slender and acuminate.

#### Subfamily: OZIINAE

Genus *Ozius* H. Milne Edwards, 1834.

Key to the Galapagos species of the genus *Ozius*.

- |  |                   |
|--|-------------------|
| Anterolateral angles decidedly produced and broken into three distinct teeth.  | <i>verreauxii</i> |
| Anterolateral angles produced, margin vaguely tridentate. A transverse line from the lateral angle back onto the gastric region. Chelipeds extremely unequal, granulose. | <i>agassizii</i>  |
| Frontal margin rather broadly rounded. Anterior portion of carapace and upper and outer surfaces of chelae and legs corrugated. Chelipeds moderately unequal.            | <i>perlatus</i>   |

*Ozius verreauxii* (de Saussure), (Velvet-fingered Crab.)

*Ozius verreauxii* H. de Saussure. *Rev. et Mag. de Zool.* 2nd série, t. V. p. 358, pl. XII, fig. 1, 1853. *Ann. Lyc. Nat. Hist. N. Y.* No. 2, p. 83, 1860. *Ozius verreauxii* A. Milne Edwards, *Crust. Rég. Mex.*, p. 277, pl. 55, fig. 4, 1880; *Faxon, Mem. Mus. Comp. Zool.*, vol. 18, p. 21, 1895; *Rathbun Proc. U. S. Nat. Mus.*, vol. 21, p. 583, 1899; *Proc. U. S. Nat. Mus.*, vol. 38, p. 587, 1910; *Zoologica N. Y. Zool. Soc.*, vol. V, no. 14, p. 158, 1924. *Xantho grandimanus* Lockington, *Proc. Calif. Acad. Sci.*, Sept. 1876.

*Name:* This species was named in honour of M. Verreaux.

*Diagnostic characters.*—Anterolateral angles decidedly produced, and broken into three distinct teeth.

*Type.*—H. de Saussure's type material on which this species was founded was secured at Mazatlan, Mexico, as long ago as 1853.

*Galapagos distribution.*—The earliest Galapagan record for this species appears to be that of Dr. Habel, in 1869 who simply records "Galapagos Islands." The *Hassler* voyage took it at James Island in 1872. The *Albatross* secured it at Charles, James, Chatham and Indefatigable Islands, 1887–88 and 1891. It was taken by the Harrison Williams Galapagos Expedition at Indefatigable Island in 1923.

*General distribution.*—Cape St. Lucas, and La Paz, Lower California; Mazatlan, Mexico; Cocos Island; Galapagos Islands and southward to the coasts of Ecuador.

*Material examined.*—One very large female and a smaller male specimen were taken by the *Arcturus* Expedition at Cocos Island, May 13, 1925.

*Technical description.*—Carapace moderately convex, finely granulose and eroded on the anterior region; posterior region smooth. Interorbital margin quadridentate, the submedian pair of teeth being broadly rounded, the outer pair similar but slightly smaller. Anterolateral margin rounded, anterolateral angles decidedly produced, broken into three distinct teeth, of which the most anterior is broad and blunt, the median, acute and separated from the preceding by a transverse line which is continued on the branchial region, the third tooth is

similar to, but only about half as large as, the second. The postlateral margins are convergent, delineated by a fine line, below which the side walls of the carapace are dorsally visible. The regions of the carapace are clearly delineated, except the mesogastric, which is vaguely outlined. There is a deep sulcus running backward from the median frontal notch and bifurcating on the gastric region. In addition to this, there is a deep transverse sulcus behind the frontal margin which bends abruptly behind the outer orbital margin and vanishes near the anterior of the mesogastric region. The orbit is subcircular with the margin raised and the lower inner angle prominent.



Fig. 82. *Ozius verreauxii*. Reduced to  $\frac{1}{2}$  of natural size.

The eyestalk is dilated basally, constricted on the outer surface below the cornea; the latter is terminal, subelliptical, shiny black.

The outer antennae have the basal joint enlarged, the distal joint stout, small, and the flagellum minute.

The inner antennae are fleshy and fold transversely within the septum.

The external maxillipeds are squarish, devoid of setae except along the inner surfaces of the ischium. The exognath is very slender, slightly curved, and bears a long internal lash. The ischium is elongate, subrectangular; the merus about as long as wide, traversed by two longitudinal sulci, and with the upper margin truncated at both corners and deeply incised between these sulci at the efferent aperture. There is a compressed three-jointed palp which arises near the inner distal margin of the merus and bends down adjacent to the inner margin. The pterygostomian regions are finely granulose but devoid of setae.

The female abdomen is broadly ovate, covering practically all of the sternal region, except that between the chelipeds, which is densely furred with setae; the abdomen consists of seven segments and is fringed marginally with fine setae. Segments two, three and four and five bear biramous pleopoda similar in shape to those of *Ozius agassizii*. The male abdomen is narrow, seven-segmented, the third segment being conspicuously the widest, the sixth the longest, the seventh triangulate. The male appendages are similar to those of *Ozius perlata*.

The chelipeds are unequal; the large one is very massive, has the merus three-sided, compressed, not projecting beyond the carapace; the carpus is convex, dilated distally; the propodus very convex on the outer surface, considerably higher than the carapace, twice as long, including the finger, as high; the propodal finger is heavy, triangulate, armed with a low basal molar, a high, median and small distal molar and bluntly pointed distally. The hinged finger is slenderer, curved, armed with a gigantic basal molar and five small rudimentary teeth, the tip is blunt; the fingers gape. Both fingers are blackish brown. This coloring extends backward on the propodus. The small cheliped is similar to the larger one except that it has longer slenderer fingers which are not gaping.

The ambulatory legs are similar; the first three pairs are subequal, the last pair being only two-thirds as long as the preceding. The joints are stout, moderately compressed laterally. The merus is decidedly the longest joint and is transversely distally by a constriction on the upper surface just below the distal margin; the carpus is dilated distally and produced diagonally to a point on the upper surface; the propodus is stout, compressed, the dactyl is slightly longer than the propodus and slenderer and is tipped with a stout horny nail. The dactyl, propodus and distal part of the carpus are covered with fine, silky brown setae, forming a velvety surface.

*Color*.—The color plate of this species made by Isabel Cooper shows it to be slate gray with bandings of coral at the meral and carpal joints of the ambulatory legs.

*Ozius agassizii* A. Milne Edwards, (Long-clawed Pebble Crab.)

*Ozius agassizii* A. Milne Edwards, *Crust. Rég. Mexico*, p. 279, pl. 55, fig. 1, 1880; Rathbun, *Proc. U. S. Nat. Mus.*, vol. 38, p. 586, 1910.

*Diagnostic characters*.—Chelipeds extremely unequal, granular. Anterolateral angles produced, margin finely tridentate. A transverse line from the anterolateral angle in to the gastric region.

*Type*.—This is one of the many species that owes its discovery to Alexander Agassiz, who secured the type at Panama. It is deposited in the Museum of Comparative Zoology at Cambridge, Mass.

*Galapagos distribution*.—Duncan Island; *Arcturus* station 54, off Hood Island, 15 feet.

*General distribution*.—*Ozius agassizii* is found from the Gulf of Panama (type-locality) to Ecuador and also in the Galapagos Islands and Cocos Island.

*Material examined*.—As unusually fine representative series of young and a few older specimens, including two egg-laden females, of this species were secured by William Beebe while diving in fifteen feet of water at Station 54, off Hood Island. (Fifteen females, and one male, including four soft-shell speci-

mens). Eleven males, seven females and one very young specimen from Tower Island, station 37, shore zone D to E, April 10, 1925. Three females were taken at Cocos Island, May 19, 1925.

*Color, habits.*—This species was found in association with the closely allied *Ozius perlatus* Stimpson, which it resembles in coloration, being a rich red-brown.

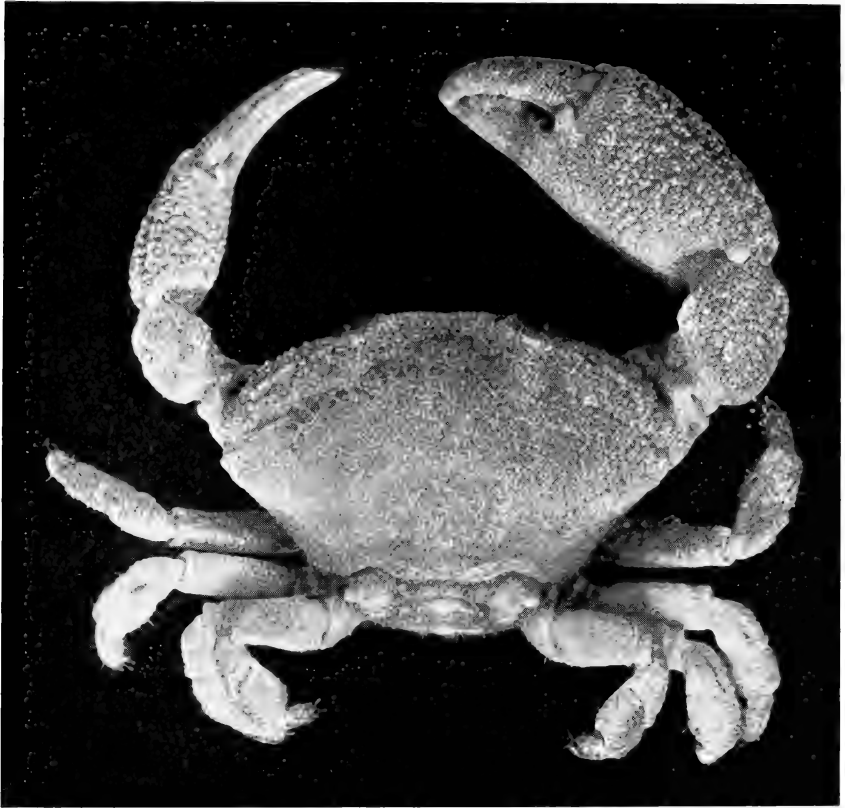


Fig. 83. *Ozius agassizii*,  $\times 1.5$ .

The present species also dwells in the crevices of coral rocks. It is enabled to entrench itself firmly therein by means of its stout sharp-pointed dactyli. Four specimens in the collection are soft-shelled. The integument is of a tough, fleshy texture, and presents all the characters of the hard shell, except inflexibility.

*Technical description.*—Carapace flat with the anterolateral margin ovate; anterolateral branchial region much produced and with three small dental prominences; the posterolateral margins decidedly converging; the branchial,

gastric and cardiac regions are delicately delineated. A distinct transverse line extends from the anterolateral angle onto the gastric region. The anterior region of the carapace is rugose, being covered with rounded granulations between which occur small pits. This rugose granulation also occurs on the lower sides of the carapace, the upper, outer surfaces of the ambulatory legs and covers the chelipeds. It differs from the rugose surface of *Ozius perlatus* which has an eroded appearance while that of *agassizii* is roundly granular. The interorbital margin is depressed, rather than straight in a dorsal view, but is deeply incised in the median line and produced into a pair of obtuse submedian teeth beyond, the ridged margin is recurved terminating in a pair of obtuse teeth near the superior inner orbital angle. The orbit is subcircular with the margin a granulose ridge, the inner superior angle being obtuse and slightly greater than the inner inferior angle.

The eyestalk is short, constricted below the cornea and finely granulate, the distal margin around the cornea being fringed with fine silky setae. The cornea is terminal, ovate, convex, shining black. It is much larger than that of *A. perlatus*.

The outer antennae have the elongated basal article lodged in the orbital sinus; the distal article is stout; the flagellum consists of about twelve articles and is almost as long as the orbital cavity is wide.

The inner antennae are very stout and fold transversely within the septum.

The external maxillipeds are densely setigerous, rectangular and very close-fitting. The exognath is an elongate rectangle and bears a long lash which is internal in position. The ischium of the engonath is a much wider rectangle, the inner edge being thickly fringed with short setae; the merus is not quite as long as wide, has the outer distal margin flaring, rounded, the upper distal margin is deeply incised at the efferent aperture; there is a stout three-jointed palp which arises near the inner distal angle of the merus and curves downward beside its inner margin.

The abdomen (female) is widely ovate, seven-segmented, fringed with long setae which also clothe the anterior sternal region. The second to fifth segments inclusive each bear a pair of subequally biramose appendages, the outer branch of which is longer, scythe-shaped and densely fringed with long hairs; the inner branch is bent inward toward the median line for the first third of its length and then slightly bowed and lying near the median line. When the crab is egg-laden, the four outer branches are spread like the spokes of a fan outside the belt around which they curve like the walls of a basket, encupping the eggs or larvae which are attached to the thread-like hairs of both appendages. The male abdomen is narrow, seven-segmented, the sixth and seventh segments being decidedly longer than the preceding ones. The male appendages are similar to those of *Ozius perlatus*.

The chelipeds are even more conspicuously unequal than are those of *Ozius perlatus*. The large one is very massive, has the merus projecting beyond the carapace and transversely grooved on the surface near the distal end and a short longitudinal groove; the propodus is expanded, about half as high as long, and is much higher than the carapace; the finger comprises about one-third of the length of the propodus and is conical and armed with five molars; the

upper finger is similar to the lower but more curved; it also has five small molars. Both fingers are slaty black with white molars and maroon tips. The small cheliped is approximately as long as the large one but it is exceedingly slender; the finger is three-fifths of the length of the propodus and is very slender, tapering and pointed. The hinged finger is similar to the lower, both are finely dentate along the inner margin and each has five larger triangulate teeth regularly interspaced among the smaller teeth. The female chelipeds are approximately as large and as unequal as those of the male. The ambulatory legs are similar, the first pair being scarcely three-fifths as long as the chelae, the remaining pairs successively decreasing in length posteriorly. All are stout, decidedly compressed laterally and have strong dactyli, tipped with a horny nail. The dactyli are densely covered with a thick felt, the propodus and distal part of the carpus are sparsely covered with the same texture.

As previously stated, the surfaces of the chelipeds and, in a less degree, the upper surfaces of the ambulatories are covered with rounded granules interspaced by pits, giving the surface a rugose appearance.

*Young.*—A young female specimen 3.5 mm. wide and 3 mm. long has all the major specific characters of the species, including the rugose granular surface on the anterior region of the carapace and legs. As is usual in very young crabs of this genus, the interorbital space appears very wide and the eyes proportionately much larger than those of older specimens. The legs are setigerous and a downy fuzziness clothes the carapace.

*Eggs, Larvae.*—The eggs are very numerous, a crab of 12 mm. greatest width carrying over 1000 eggs. They are minute, less than 0.5 mm. in diameter, golden spheres individually attached to the long plumose setae of the pleopoda.

One one of the ovigerous females the eggs, scarcely half a millimeter in diameter, show the well developed opaque embryos with tiny black eye-spots.

Another specimen shows the embryos in a much more advanced stage. These are about 0.7 mm. in diameter, chocolate brown, with huge, black, elliptical eye-spots.

*Ozius perlatus* Stimpson. (Eroded Pebble Crab.)

*Ozius perlatus* Stimpson, *Ann. Lyc. Nat. Hist. N. Y.*, vol. VII, p. 83, 1860  
A. Milne Edwards, *Crust. Rég. Mexico*, p. 278, pl. 55, figs. 2a-c, 1880.

*Diagnostic characters.*—Chelae moderately unequal. Anterior portion of carapace and upper and outer surfaces of chelae and legs corrugated. Distinguished from the analogous West Indian species, *Ozius reticulatus* Desbonne and Schamm, by the more broadly rounded frontal margin of the present species.

*Type.*—The type material "was found in considerable numbers at Cape St. Lucas, by Mr. Xantus and was deposited in the United States National Museum."

*Galapagos distribution.*—*Arcturus* station 37, shore zone D to E, Tower Island, and station 54, off Hood Island where this species was taken in great abundance, establish the first Galapagan records for this species.

*General distribution.*—*Ozius perlatus* Stimpson has been taken from Cape St. Lucas, Lower California, and at Panama along the tide-line and in shallow water; also at the Galapagos Islands.

*Material examined.*—The material secured by the *Arcturus* Expedition extends the range of this species to the Galapagos archipelago. Twenty-two specimens, ranging in size from minute organisms to very large forms, some of which are egg-laden, were secured at Station 37, shore zone D to E, Tower Island, April 16, 1925, and a representative series of thirty specimens was



Fig. 84. *Ozius perlatus*,  $\times 1.9$ .

secured at station 54, off Hood Island, by William Beebe, while diving in 15 feet of water.

*Color and habits.*—These curious little red-brown organisms were difficult to distinguish from the coral rocks in the crevices of which they were fitted like bits of living mosaic, the rugose surface of their bodies further accentuating the similarity.

*Technical description.*—Carapace quite broad (28 mm. wide, 17 mm. long), depressed, anterolateral margins broadly rounded, posterolateral margins decidedly converging. Interorbital margin relatively straight in a dorsal view, depressed, and transversely channelled, but actually decidedly broadly obtusely bidentate on the frontal margin. The female abdomen is seven-segmented,



broadly rounded distally, and fringed with setae, as is the anterior sternal region; the second to fifth segments bear biramose pleopoda, the outer branch being curved, scythe-like and the inner one bent inward toward the median line for the first third of its length, and with the distal two-thirds slightly arcuate and lying near the median line. The male abdomen is also seven-segmented, the first and second segments are dorsal, the third segment is conspicuously the widest; the fourth, fifth and sixth segments being successively longer; the terminal segment is triangular. The first pair of male appendages are stout basally, taper distally and are slightly tortuous and three-sided, the margins of this distal region are finely spinous, the apex is a spoon-shaped concavity which is continued as a groove on the inner of the three sides. The second pair of appendages are exceedingly slender, rodlike processes which are finely attenuated distally and curved inward in a deep semicircle, then curved downward in another semicircle which approximately parallels the first curve. The anterior region of the carapace, upper and outer surface of the chelipeds and of all the ambulatory legs are corrugated, the raised areas being irregularly shaped and reticulating, the channels deep, eroded; the posterior region is flat and smooth except for a few fine granulations. The branchial regions are distinctly delineated; the pterygostomian regions are coarsely granulated.

The orbit is small, circular, with the margin slightly ridged. The eyestalk is very short, bulbous, filling the ocular cavity; the cornea is terminal, obliquely set, exceedingly small and slightly convex, shining black.

The outer antennae are situated at the inner lower orbital angle and have the basal article narrow and slightly projecting, the distal article minute and the flagellum quite small.

The inner antennae are well-developed and fold transversely in the antennal septum.

The external maxillipeds fit closely in the aperture and are beset with clusters of setae; the ischium is subrectangular, longitudinally channelled near the median area and fringed with fine setae along the inner margin; the merus is as wide and approximately half as long as the ischium and traversed by two longitudinal sulci, the inner of which is a continuation of the sulcus on the ischium, and the outer one, in line with the depression between the exognath and endognath; the distal margin is deeply incised at the efferent aperture, and a tapering, three-jointed palp arises from near the inner distal angle; the exognath consists of a short, broad, bent base, an elongate rectangular second joint, which extends almost to the distal angle of the merus, and is slightly depressed distally and bears a long, flexible cylindrical whip which is flagellum-like and fringed with plumose setae.

The male chelipeds are massive and conspicuously subequal, having the basis and ischium short and stout, the merus swollen, three-sided, with the lower distal angle acutely produced; the carpus is broadly rounded outwardly and produced knob-like on the upper inner side; the propodus is broad and high and dilated distally; the fixed finger is massive, gaping and bears three distinct molars; the hinged finger swings obtusely and is a trifle slenderer than the basal. It also bears three small molars. Both fingers are slaty black tipped with maroon. The small cheliped differs from the large only in size and in having

the fingers meet along the cutting edge. As previously noted, both the chelipeds and ambulatories are rugose on the upper and outer surfaces. The first and second pair of ambulatory legs are subequal, the third pair, decidedly the longest, while the fourth pair are conspicuously the shortest. They are all similar in structure being stout and somewhat compressed laterally, except the dactyli which are cylindrical, short, tapering to a strong horn-like point; the sides of the dactyli are covered with felt-like setae and this extends in clusters upon the propodus.

*Young*.—A very young male crab,—4 mm. wide and 3 mm. long,—bears all the specific characters of the species but differs from the above described older specimens in being finely, conspicuously setigerous all over; in the absence of the eroded surface of the carapace and chelae, which is finely granulate on the young specimen, in having the fingers meeting, not gaping, and the molars more conspicuous than in the older worn specimen. In the little crab the interorbital space is proportionately much wider than in the older crabs, giving the little creature a quaint, big-eyed, flat-faced expression.

*Eggs*.—The eggs are minute, spherical, golden and very numerous. A crab about one inch wide carried approximately 1500 eggs.

#### Subfamily: ERIPHIINAE

#### Genus *Eriphia* Latreille, 1817

#### Key to the Galapagos species of the genus *Eriphia*.

Carapace with granulations covering the entire gastric and hepatic regions and the anterior portions of the branchial regions and present also in a reduced form on the back.

*granulosa*

Carapace with scale-like tubercles, each of which is ringed with setae, on the anterior borders of the carapace. Chelipeds similarly ornamented.

*squamata*

*Eriphia squamata* Stimpson, 1859. (Beaded Crab.)

*Eriphia squamata* Stimpson, *Ann. Lyc. Nat. Hist. N. Y.*, vol. 7, p. 56, 1859; Sydney I. Smith, *Rept. Peabody Acad. Sci.*, p. 90, 1869; A. Milne Edwards, *Crust. Rég. Mexico*, p. 339, pl. 56, fig. 3, 1880; Rathbun, *Proc. U. S. Nat. Mus.*, vol. 38, p. 544, pl. 41, fig. 1, 1910.

*Diagnostic characters*.—Chelipeds conspicuously unequal with the scale-like tubercles of wrist and hand squamous and each tubercle ringed anteriorly with fine setae.

*Type*.—Professor Stimpson's type came from Cape St. Lucas, Lower California and was deposited in the "Museum of the Smithsonian Institution."

*Galapagos distribution*.—Three large females, two of which were ovigerous, were taken at Eden Island, Galapagos, by the Harrison Williams Expedition and three small females, one of which is ovigerous, and two small males taken at Station 54, Hood Island, by the Arcturus Oceanographic Expedition comprise the Galapagos records for this species.

*General distribution*.—This species has been recorded from Cape St. Lucas, Lower California; the west coast of Mexico; Panama; Nicaragua; Peru and Chile.

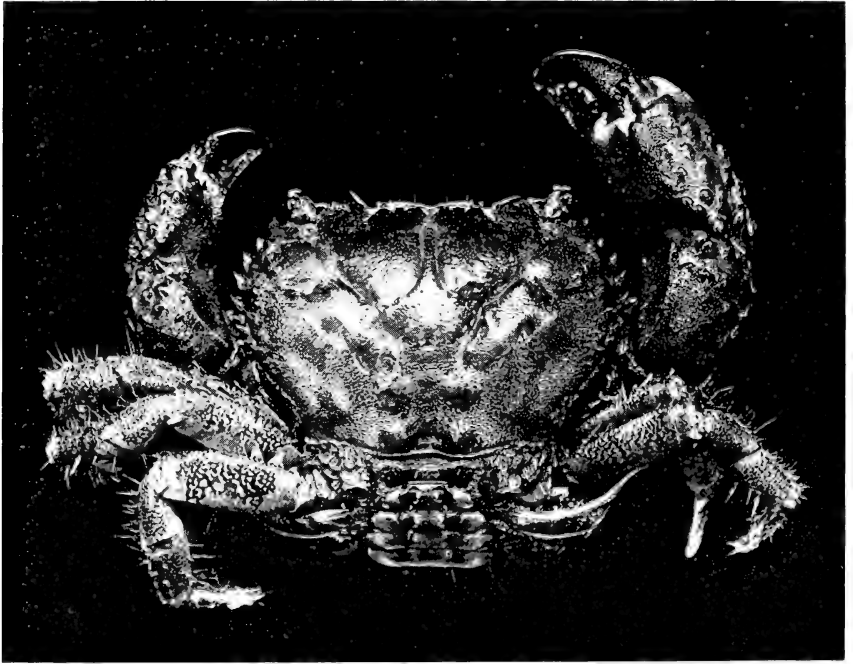


Fig. 85A. *Eriphia squamata*,  $\times 1.7$ .

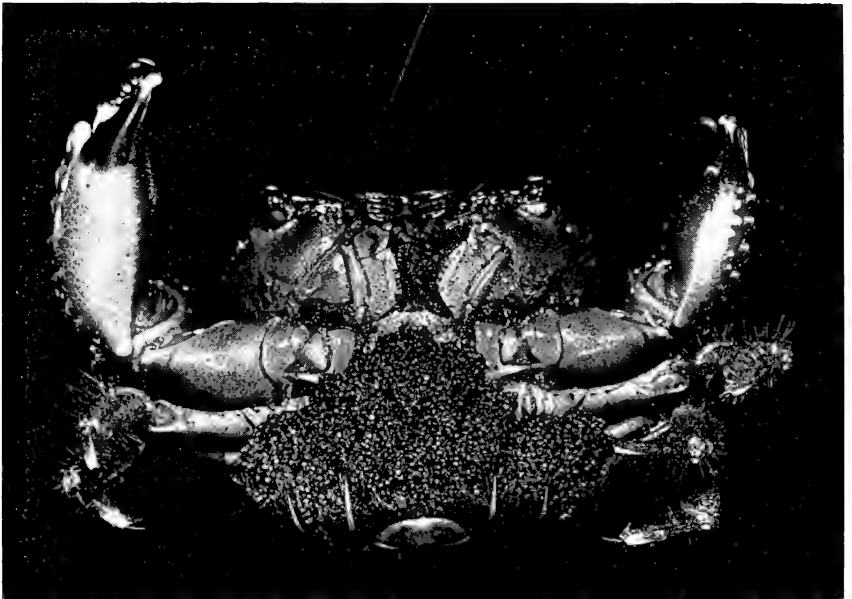


Fig. 85B. Ventral view of same specimen shown in Fig. 85A.

*Material examined.*—Three small females, one of which is ovigerous, and two small males were taken at Station 54, off Hood Island by William Beebe, while diving in fifteen feet of water. Dr. Beebe states that these crabs were found in crevices of the coral rock which they so much resemble. One large female was taken at Cocos Island, May 13, 1925, by the *Arcturus*. Three large females, two of which are ovigerous, were taken at Eden Island, Galapagos, by the Harrison Williams Galapagos Expedition.

*Color.*—Purplish red shading into magenta.

*Technical description.*—The anterior three-fifths of the carapace is very wide as contrasted with the posterior two-fifths, whose sides converge abruptly. The greatest width of the carapace is 30 mm.; the interorbital space is 18 mm.; the length of the carapace is 23 mm. The carapace is ornamented anteriorly with squamous granules and tubercles which in some places simulate rugae. The regions of the carapace are distinctly indicated by sulci. The interorbital space is truncate; the margin is channeled and is divided into two major lobes, a deep longitudinal median sulcus extending back on the gastric region. The anterolateral margin is convex and is armed with six (including the postorbital), acute, forward-curved teeth, of which the anterior three are subequal and larger. The last three gradually decrease in size posteriorly. Although six is the usual number of spines on the lateral border, occasional large specimens have seven, or, more rarely, eight teeth. Some specimens I have examined have six teeth on one side, and eight on the other, the two extra teeth apparently being irregular development of squama of the carapace pushed out to the margins. The pterygostomian region is sparsely setiferous.

The female abdomen is oval, seven-segmented, with the entire margin densely fringed with hairs, as is the sternal area opposite the distal abdominal segment. The second to fifth segments inclusive bear paired biramous appendages. The outer branch of each appendage is long and curved; the inner branch consists of a short, proximal segment and a long distal segment. Both branches are heavily fringed with long, plumose setae. The radial basket-forming position assumed by these branches in supporting the eggs is well-illustrated in figure 85B. The paired female genital apertures, situated in the sternal plate which is opposite to the second ambulatory legs, are near the median line of the cavity and are curiously overarched by a tongue-like calcareous process which is derived from the sternal plate; the under margin of the aperture is heavily fringed with coarse black setae.

The male abdomen is narrow, seven-segmented with the apex triangulate. The first pair of male appendages are well developed rods; the second pair are nearly as long as the first and are very slender with distal end forming one and one-half or two coils of a spiral.

The inner antennae are typical and fold transversely with the fossett.

The external antennae are small; the basal segment is firmly anchylosed and situated at the outer end of the antennular fossett; there is one large squama on it; the second and third articles are compressed; the flagellum consists of about twenty-six articles and reaches to the base of the eyestalk.

The external maxillipeds fit closely into the buccal cavity except for a notch at the efferent aperture. The ischium is rectangular with a deep longi-

tudinal groove on its outer surface; the merus is about half as long as the ischium and has the distal margin angulated; the three-jointed palp arises from the inner distal margin of the merus.

The chelipeds are conspicuously unequal in both sexes, robust; the merus is smooth except for a single sharp tooth at the upper distal angle and a similar obtuse tooth at the lower distal angle; the carpus and propodus are smooth on the inner and lower sides but the outer and upper sides are covered with large squamose tubercles forming a close-set, scale-like pattern. Each squama is fringed anteriorly with fine dense hairs. The fingers are well developed; the movable finger of the large cheliped has a stout tooth basally, and is strongly curved apically; the fixed finger bears a trilobed molar basally; the fingers of the smaller cheliped are slenderer, uniformly dentate, not gaping.

The ambulatory legs are compressed, subequal, set with clusters of hairs, especially on the distal three joints.

*Young*.—One of the young female specimens secured at Station 54, measures 4 mm. long; 6 mm. anterior diameter. It conforms in all details to the description of the adult, but the young specimen is covered with sparsely set long hairs, especially on the ambulatory legs and dorsal surface of the carapace and to these is fastened a protective coating of algae, bryozoa, bits of shell and sand.

*Eggs*.—One female only 7 mm. wide, 5 mm. long was carrying about 100 embryos. These were spherical with slit-like black eyespots.

The large female photographed (Fig. 85 A and B) carried several thousand small chocolate-colored spherical eggs.

*Eriphia granulosa* A. Milne Edwards. (Also known as "Beaded Crab.")

*Eriphia granulosa* A. Milne Edwards, *Crust. Rég. Mex.* p. 339, pl. 56, fig. 2, 1880; Rathbun, *Proc. Wash. Acad. Sci.* vol. 4, p. 282, 1902; *Zoologica*, N. Y. Zool. Soc. vol. 5, no. 14, p. 158, 1924.

*Diagnostic characters*.—As stated by Prof. Milne Edwards, this species is readily distinguished from all other members of the genus by the presence of granulations which cover all the gastric region, the hepatic regions, the anterior portions of the branchial regions, and are also evident in a reduced form on the back.

This species may prove to be only a subspecies of *Eriphia squamata* Stimpson.

*Type*.—The type, a unique specimen, is in the Paris Museum and is labelled "Chile."

*Galapagos distribution*.—One young specimen, collected in rock pools, Eden Island, April 26, 1923, by the Harrison Williams Galapagos Expedition, was identified by Miss Rathbun as *Eriphia granulosa*. The same writer reports six specimens from Tagus Cove, Albemarle Island, secured by the Hopkins-Stanford Expedition and cites Chatham Island, from material collected by Dr. W. H. Jones, U. S. N.

*General distribution*.—Chile (type-locality); Galapagos Islands; and Cocos Island (*Arcturus* Expedition).

*Material examined*.—One female, taken at Cocos Island, by the *Arcturus*, May 3, 1925.

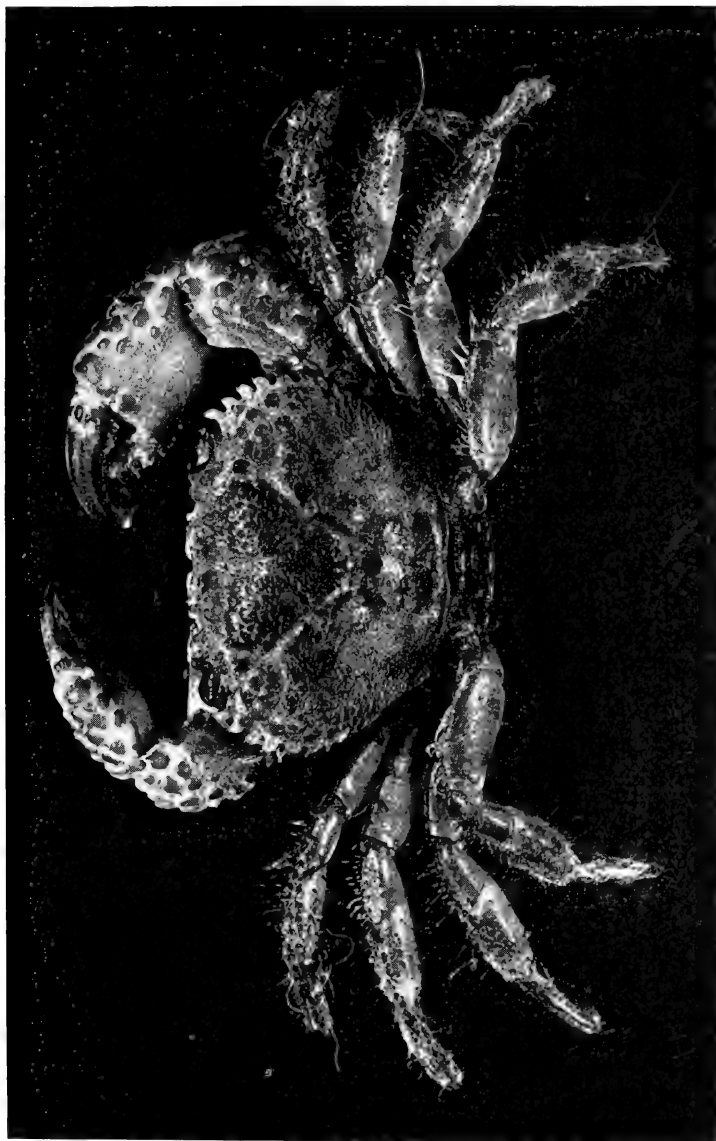


Fig. 86. *Eriphia gonagra*,  $\times 1.5$ .

*Color*.—Carapace raisin purple; setae brownish.

*Technical description*.—This species is very closely related to *Eriphia squamata* of the West Coast, and also to *E. gonagra* of the East Coast. It is frequently found in association with *squamata*, both species inhabiting the crevices of the coral rock bottoms.

*Eriphia granulosa* has the carapace much flatter and the frontal region less deflexed than that of *squamata*. It is as long and only about five per cent narrower than that of *squamata*, but the convexity of *squamata*, when contrasted with the flattish carapace of *granulosa*, causes the latter to appear much narrower. The frontal border is divided into four lobes; the larger, inner pair being the wider and separated from each other by a deep median groove which terminates in a notch anteriorly. The regions of the carapace are clearly delineated; the hepatic region being deeply circumscribed. The superior orbital border is microscopically granulated and bears two coalesced lines indicating closed sinuses; the external angle is a sharp tooth, similar to and slightly larger than those of the anterolateral border. The inferior orbital border is smooth and terminates at its inner end in a blunt tubercle. The anterolateral border is cut into five, sharp, forward-curved teeth (in addition to the postorbital tooth) which successively decrease in size posteriorly. The gastric, hepatic and anterior portions of the branchial regions are covered with tubercles and rough granulations.

The chelipeds are quite similar to those of *squamata*, being unequal, and having the upper and outer faces of the carpus and propodus covered with large, close-set, rounded tubercles, each of which is fringed around the anterior half of its base with short, brown setae. The fingers are strong, deep purplish red; the curved, hinged finger of the larger cheliped bears a huge, sub-basal molar tooth.

The ambulatories are similar to those of *squamata*.

#### Genus *Eriphides* Rathbun

*Eriphides hispida* (Stimpson). (Purple Bristle Crab.)

*Eriphia hispida* Stimpson, *Ann. Lyc. Nat. Hist. New York*, vol. 7, p. 218, 1860.

*Pseuderipha hispida* A. Milne Edwards, *Crust. Rég. Mex.*, p. 340, pl. 56, fig. 1, 1880.

*Eriphides hispida* Rathbun, *Proc. U. S. Nat. Mus.*, vol. 38, p. 586, 1910;

*Proc. Washington Acad. Sci.*, vol. 4, no. 8, p. 282, 1902; *Zoologica, N. Y. Zool. Soc.*, vol. 5, no. 14, p. 158, 1924.

*Diagnostic characters*.—Carapace and legs purplish, covered everywhere with coarse, short, stiff, black setae, which usually arise from tubercles.

*Type*.—Professor Stimpson's type, which he states was deposited in the "Museum of the Smithsonian Institution," was found on the west coast of Central America, by Captain J. M. Dow.

*Galapagos distribution*.—Tagus Cove, Albemarle Island, (Hopkins-Stanford Expedition; also Albatross); Eden Island, (Harrison Williams Expedition); Tower Island, Shore zone, Station 37, (*Arcturus* Expedition).

*General distribution*.—Central America, Panama and the Galapagos Islands.

*Material examined*.—Five males, two being very small, and two females from Station 37, shore zone, Tower Island, Galapagos, taken by the *Arcturus*;

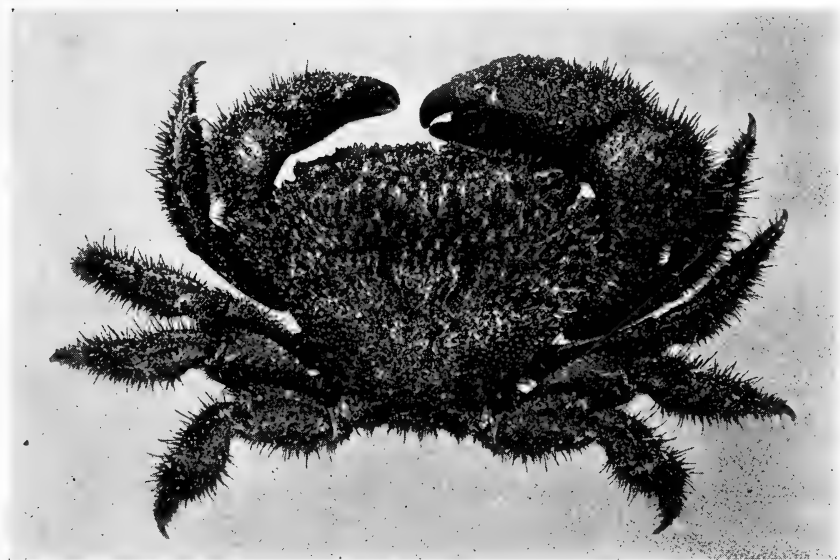


Fig. 87A. *Eriphides hispida*, adult. Reduced to  $\frac{3}{4}$  of natural size.

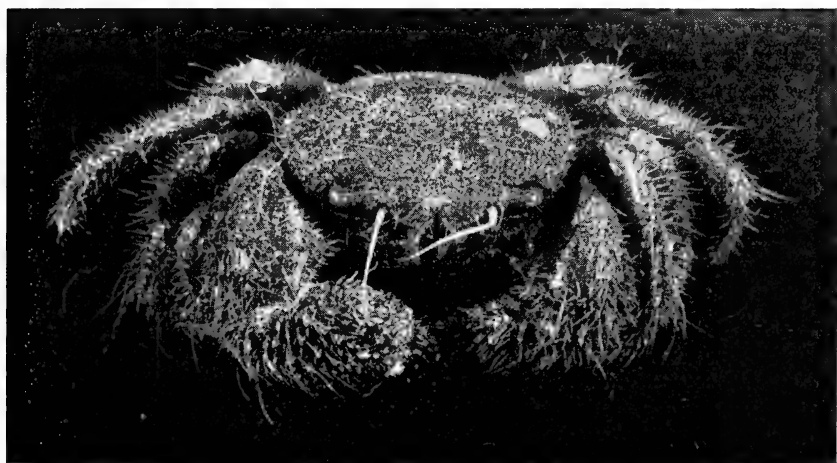


Fig. 87B. *Eriphides hispida*, young, enlarged  $7\frac{1}{2}$ .



one male from Eden Island (tag 2111) Galapagos archipelago, taken by the Harrison Williams Galapagos Expedition (photographed specimen, fig. 87A).

*Color*.—Carapace and feet purplish beneath the black setae. (Stimpson.)

*Habits*.—In his "Galapagos—World's End" (p. 131) Dr. Beebe gives the following vignette of *Eriphides hispida* and its neighbors:

"The crabs should have a whole chapter to themselves, ever more wonderful scarlet chaps who came down from the upper caves to see what we were doing, appearing and disappearing like flickering flames among the smoky sea-weed. Bristly crabs inhabited small individual lava cells which were so like the hollows worn by sea-urchins that it was certain that they were worn only by the drawing and quartering of the rightful architects. Yet they seemed to fit strangely well into their niches, and could not be pried out. They were ever ready to pinch with their claws, or to draw blood by shutting down on a finger with any of their walking legs."

*Technical description*.—Carapace; maximum width 51 mm.; 38.5 mm. long; interorbital border 28 mm. Carapace broader through the anterior two-thirds, decidedly narrower posteriorly; rather flattish with the frontal border somewhat deflexed; areolations only faintly indicated. Carapace covered with low squamose tubercles which are larger and more abundant toward the anterior region. Each tubercle is fringed anteriorly with sort stiff setae and the posterior part of the carapace also has bristly setae between the tubercles; the frontal border is bilobed in the median region, a deep sulcus running back from this median sinus onto the gastric region; the frontal margin is irregularly set with uneven denticle-like tubercles. Just below these the pterygostomial region is also tuberculate. There are six teeth (including the postorbital tooth) on the anterolateral margin, the first four are large and bi- or tri-dentate, the posterior two are smaller and acute. The superior orbital margin is set with denticles; the inferior orbital margin is also denticulate and has a deep hiatus near the external angle.

The male abdominal belt is narrow, seven-segmented, with the distal segment triangulate. The first pair of male appendages are slender, curved rods with a deep channel on their inner side; the distal end is small, pointed and channelled by this groove. The second pair of male appendages consist of a stout, short basal joint and an exceedingly slender attenuated process which extends almost as far forward as the first pair and then curls forming two loops of a spiral.

The female abdomen is oval, narrow, seven-segmented, wider throughout the distal half. The four pairs of female appendages are biramose and very setigerous, the outer being curved, the inner biarticulate.

The eyestalk is bulbous basally, constricted abruptly below the cornea and thence tapering. The cornea is small and set obliquely at the end.

The inner antennae are small and fold transversely within the septum.

The external maxillipeds are squarish and close the buccal cavern tightly except the aperture of the efferent channel, and a very narrow space between ischia, which latter is covered by sieve-like setae. The exognath is elongate and bears a toothlike projection on its inner distal margin and a slender palp which arises from its distal end; the ischium is subrectangular and is traversed

on its outer surface by a longitudinal depression and is denticulate on its inner margin; the merus is about one-half as long as the ischium, is trapezoidal, with a slight emargination below the efferent aperture; the palp arises just inside this emargination and the inner distal angle of the merus is angulated beneath the palp; the palp is rather fleshy and consists of three joints.

The chelipeds are conspicuously unequal in both sexes, but this inequality is more pronounced in the male. The three basal joints are small but strong; the merus is compressed and appears to be smaller than the carpus; there is a decided transverse subdistal constriction on the upper, outer and inner faces of the merus; the carpus is convex on its outer surface, dilated distally, and in the small cheliped is about as large and more swollen than the palm of the propodus, while the carpus of the large cheliped is almost as large as that propodus. The upper surface of the merus is finely tuberculate and covered with short, stiff bristles; that of the carpus is coarsely tuberculate and rugose and also is covered with bristles. The propodus of the great chela is about twice as long as the carpus, the fingers comprising approximately one-half of this length; the palm is quite as high as the carapace and convex; the upper surface is coarsely and rather thickly tuberculate as is also the upper half of the outer surface, the tubercles vanishing along a diagonal line extending from the base of the hinged finger to the lower basal margin; the remaining lower outer surface of the palm is devoid of bristles and is covered with low, flat scale-like tubercles. On the small chela, the entire outer surface of the propodus is covered with bristles and tubercles. The fingers are purplish black, those of the large chela are widely gaping except at the tip; the propodal finger is stout and bears one large median tooth; the hinged finger is longer and curved and bears a small, sub-basal tooth; the fingers of the small cheliped are spoon-shaped at the tip and meet for the greater part of their inner faces, there being only a small gape basally and no teeth. The female chelipeds are ornamented similar to those of the males.

The great chela of the male projects conspicuously beyond the carapace, its width at the wrist being almost equal to one-half of the width of the carapace.

The four pairs of ambulatory legs are similar in structure, stout, strong, with the upper, outer, and in a less degree, the lower surfaces densely covered with short, stiff bristles. The first and second pairs are subequal in length, the third pair is a little shorter, reaching to not quite to midway the dactyl of the second leg; the fourth pair of legs are conspicuously shorter reaching only midway the propodus of the third pair. All four pairs of legs have the meral joint long, wide and flattened with a transverse subdistal constriction and the upper margin finely denticulate; the carpal joint is narrow proximally, wider distally and about as long and thick as the propodal joint; the latter narrows slightly distally and is stout and convex outwardly; the dactyli are about three-fourths as long as the propodi and are very strong, cylindrical, curved, terminating in a strong, horny spine.

## Subfamily: TRAPEZINAE

Genus *Trapezia* Latreille, 1825*Trapezia cymodoce ferruginea* Latreille. (Enamelled Crab.)

*Trapezia ferruginea* Latreille, *Encyc. Meth. Ent.*, vol. 1, p. 695, 1825.

*Trapezia cymodoce* Dana, *Crust. U. S. Explor. Exped.*, pt. 1, p. 257, 1852, atlas pl. 15, fig. 5, 1855; A. Milne Edwards, *Crust. Rég. Mexico*, p. 342, 1880; S. I. Smith, *Boston Soc. Nat. Hist.*, vol. 12, p. 287, 1869; Lockington, *Proc. Calif. Acad. Sci.*, for Sept., 1876; Faxon. *Mem. Mus.*, vol. 18, p. 22, 1895.

*Trapezia cymodoce ferruginea* Rathbun, *Proc. U. S. Nat. Mus.*, vol. 38, p. 586, 1910.

*Diagnostic characters.*—This is a rather large species compared with its American congeners. Frontal margin six-lobed without a submarginal groove. Breadth and width almost equal. One vague median lateral tooth.

*Type.*—I have not been able to ascertain where Latreille's type material is deposited. It came from the Indo-Pacific region.

*Galapagos distribution.*—One ovigerous female from Station 37, zone F, Darwin Bay, taken by the *Arcturus* appears to be the only Galapagos record for this widely distributed species.

*General distribution.*—This species, so often confused with its congeners, has been definitely recorded from Acapulco, Mexico, by Dr. Faxon, and from the Pearl Islands, Bay of Panama, by Milne Edwards, S. I. Smith and Faxon. It has also been recorded from the Indo-Pacific region by Latreille, Dana, Faxon and Rathbun. The *Arcturus* material extends the range of this species to include Cocos Island and the Galapagos.

*Material examined.*—One ovigerous female from Station 37, zone F, Darwin Bay, Galapagos Islands; three males and one female from Cocos Island, May 19, 1925, secured by the *Arcturus* Oceanographic Expedition.

*Color.*—In life this little crab is a bright orange red with brownish black eyes and wood-brown fingers. Preserved specimens are usually faded to a vivid orange. It has a highly polished shining surface.

*Technical description.*—Carapace 11 mm. long, 13.5 mm. maximum width, moderately convex in both directions, narrower in the postorbital regions than in the median diameter. Interorbital space 7 mm. wide, with the margin thin and grooved above, six-lobed, the median pair being smallest, most acute, the intermediate pair being the widest and rather rounded; the external pair are rounded, and slightly deflexed, intermedial in size between the first and second pairs, and with the outer distal side a trifle bent downward. The superior orbital margin is unbroken; the postorbital angle is acute; the lateral margins are strongly curved, the carapace being widest in the middle, the margins converging anteriorly where the width between the postorbital angles 12.5 mm. the maximum median width being 13.5 mm. and the posterior margin width being 5.5 mm. There is a shallow vague tooth midway, which the lateral margins converge decidedly behind this tooth, being only 5.5 mm. apart at the posterior margin. There is an irregular row of punctae behind the frontal and orbital margins. Scattered punctae are also present on the dorsal surface of the carapace and legs.

The female abdomen is very broad, subcircular distally, the first and second segments are short and narrow and are visible dorsally; the third, fourth,

fifth, sixth and seventh segments successively increase in length, the last one being the widest of the series and having its margin semicircular. The margins of all the segments are fringed with short, thick setae. The second to fifth segments inclusive bear the paired biramous appendages to which the eggs are attached. Each appendage consists of a short base supporting a long curved,



Fig. 88. *Trapezia cymodoce ferruginea*,  $\times 3$ .

heavily fringed outer branch which lays parallel to the outer margin of the abdomen, and a slender inner branch, consisting of an inbent proximal joint and a distal portion consisting of ten subequal articles, which are heavily fringed with long setae, to which the eggs are attached.

The male abdomen is narrow, triangulate, five-segmented, the first and second segments are extremely short; the third segment is composed of the third, fourth and fifth segments anchylosed, but with segment lines visible near the outer margin; the fourth segment is not half as long as the preceding and

is rhomboidal; the fifth segment is very short with its free margin rounded. The first pair of male appendages are slender curved rods, with an acute distal process which is set with short, rough setae on the inner surface.

The eyestalk is short, regularly cylindrical and produced on its upper and under surfaces into uneven, rounded processes that project upon the cornea. The cornea is oval, and very convex, set obliquely at the terminal; the facets are very minute.

The antennulae are moderately large and fold transversely within the fossett.

The external antennae are small; the three basal joints are placed diagonally at the outer side of the basal joint of the antennulae, reaching to the sinus between the preorbital and second frontal lobes, beyond which the slender, 24-jointed flagellum extends almost to the distal margin of the cornea.

The external maxillipeds are large, squarish, close-fitting, with a very large palp. The basal joint of the exognath is wide; the second joint is dilated on its inner margin and extends almost to the distal edge of the merus; the palp is very long, slender, curved and setigerous; the ischium is as broad basally as it is long and has the inner margin broadly rounded, narrowing distally; there is a deep sulcus subparallel to the inner margin; the merus is about three-fourths as long as the ischium and has its three margins rounded; the large palp arises from the inner distal border of the merus and curves downward around the merus, the tip of the distal joint reaching slightly more than halfway the length of the ischium and the tuft of hairs on the tip of the palp reaching to the base of the ischium.

The chelipeds are moderately unequal in both sexes, smooth and shining, with a few punctae irregularly scattered on the surface. The merus joint is short and wide, being produced on its anterior surface into a wing-like process which is sharply serrated into four or five (rarely six) teeth; the anterior distal margin is also serrated; the posterior outer proximal margin is sharply angulated; the carpus is about two-thirds as long as the merus and is produced to a blunt tooth on its inner margin and is convex on its upper and outer surfaces; the propodus is a little longer than the width of the carapace and it is stout and folds obliquely under the front of the carapace, the tips of the fingers reaching to the base of the merus of the other chela; the propodal finger comprises about one-third of the length of the propodus and is rather stout with the tip acute and upcurved; the cutting edge is serrated by thirteen weak teeth, one large tooth is fourth in position from the base; the hinged finger is thinner and more sharply curved distally; it has one strong basal tooth and two or three weak ones on the cutting edge; the fingers fit closely upon each other with the curved tips crossing.

The four pairs of ambulatory legs are practically subequal, the more dorsal point of attachment making the fourth pair appear shorter, though in reality they are as long as the others. Each has the meral joint broad, half as wide as long; the carpus is narrow basally; produced on its anterior distal margin, and is about half as long as the merus; the propodus is almost as long as the merus but is narrower and is produced at its distal end into a lateral rounded process on each side between which the propodus articulates; there is a smaller, roundish

process on the posterior side of the dactyl which coördinates with the propodal process; the dactyl is stout, compressed, curved at the tip and almost as long as the propodus. The distal half of the carpus and entire propodus are moderately set with long stiff setae and the dactyl is thickly set with similar setae.

*Eggs and zoea.*—The above described female is carrying about fifteen hundred small yellow oval eggs in which the developing embryos are visible. They are about 0.25 mm. diameter and show the eyes as small black circles; the uncurled embryos show a smooth globular carapace and narrow segmented abdomen with slender rhipidura. The feet are very frail.

Genus *Ectaeesthesius* Rathbun, 1899

*Ectaeesthesius bifrons* Rathbun.

*Ectaeesthesius bifrons* Rathbun, *Proc. U. S. Nat. Mus.*, vol. 21, p. 591, pl. 42, figs. 12-14, 1899.

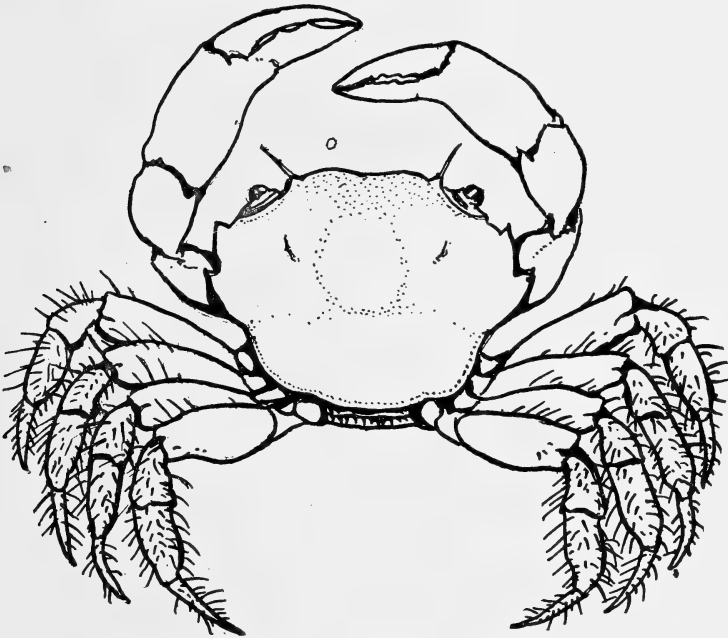


Fig. 89. *Ectaeesthesius bifrons*,  $\times$  about 4 (After Rathbun).

*Diagnostic characters.*—Orbital fissure closed; sides two-toothed.

*Type.*—One ovigerous female from off Chatham Island, Galapagos Islands (Albatross station 2809), 45 fathoms; deposited in the United States National Museum.

*Galapagos distribution.*—Off Chatham Island, 45 fathoms.

*General distribution.*—Known only from the type-locality.

*Material examined.*—None.

*Technical description.*—(As given by Rathbun): “Carapace slightly convex in both directions, about three-fourths as long as wide, antero-lateral margin arcuate, postero-lateral margins sinuous and rapidly converging. Surface smooth, except near the front and lateral teeth, where fine granulation may be detected with the lens. Front nearly half the width of the carapace, slightly arcuate, almost imperceptibly bilobed, edge thin, retreating at the outer angles. Just above, behind, and parallel to the margin, at a distance of about 0.2, of a millimeter, is a sharp ridge which is slightly interrupted at the median line. Orbit less than half the width of the front; outer angle inconspicuous, not advanced beyond the general outline of the orbital margin. The tooth at the lateral angle of the carapace is situated a little in front of the middle of the length of the carapace and is subacute. The first tooth of the antero-lateral margin is about one-third the distance between the orbital angle and the lateral tooth and is obtuse. The abdomen of the mature female is narrow; third, fourth, and fifth segments subequal in length as well as in width; sixth of the same width, but longer; seventh narrower, length and breadth subequal, extremity rounded. Peduncular joints of antennae short.

Merus of chelipeds extending but little outside the carapace, trigonal, widest near the middle. Carpal tooth large and sharp. Manus with the inner surface swollen toward the proximal end, as in *Grapsillus*; margins smooth and rounded; superior margin slightly convex, inferior margin sinuous, that of the pollex being concave. Dactylus longer than the superior margin of the palm. Fingers not gaping, marked with a few lines of punctae; dactylus without teeth; pollex of the larger cheliped with one low tooth on basal half and two teeth and a few denticles on terminal half; in the smaller cheliped the teeth of the pollex are all on the terminal half. The ambulatory legs are of the same nature as those of *Grapsillus*; dactyli nearly as long as the propodi.

*Dimensions.*—Ovigerous female: length, 7 mm.; width, 9.7 mm.; width of front, 4.4 mm.; exorbital width 7.2 mm.”

#### Family: GRAPSIDAE

#### Subfamily: GRAPSINAE

#### Genus *Grapsus* Lamarck 1801

*Grapsus grapsus* (Linnaeus), 1758. (Rock Crab; “Sally Lightfoot.”)

*Pagurus maculatus* Catesby, *Nat. Hist. Carolina, Florida and Bahama Islands*, vol. 2, p. 36, pl. 36, fig. 1, 1743.

*Cancer grapsus* Linnaeus, *Sys. Nat. ed. 10*, vol. 1, p. 630, 1758.

*Grapsus pictus* Latreille, *Hist. Nat. Crust.*, vol. 6 and 7, p. 69, 1802, and 1803.

*Grapsus webbi* Milne Edwards, *Ann. Sci. Nat. Ser. 3, Zool.*, vol. 20, p. 16, and p. 167 (133), 1853.

*Grapsus goniopsis pictus* de Haan, *Fauna Japon. Crust.*, p. 33, 1835.

*Grapsus maculatus* Milne Edwards, *Ann. Sci. Nat. ser. 3, Zool.*, vol. 20 p. 167 (133), pl. 6, figs. 1–1n, 1853.

*Grapsus ornatus* Milne Edwards, *ibid.*, vol. 20, p. 168, (134) 1853.

*Grapsus altifrons* Stimpson, *Ann. Lyc. Nat. Hist. New York*, vol. 7, p. 230, 1860.

*Grapsus grapsus* Ives, *Proc. Acad. Nat. Sci. Phila.*, for 1891, p. 90; *Faxon, Mem. Mus. Comp. Zool.*, vol. 18, p. 30, 1895, Rathbun, *Bull. 97 U. S. Nat. Mus.*, p. 227, pls. 53–54, 1917; *Bull. Am. Mus. Nat. Hist.*, vol. 48, p. 629, 1923.

*Diagnostic characters.*—Carapace vivid scarlet, discoidal; carpal spine

ovate-acuminate; fingers spoon-shaped. Front vertical, depth in median line slightly greater than half its length.

*Type*.—America and Ascension Island. The type material is no longer extant.

*Galapagos distribution*.—Eden, Tower, Chatham, Hood, Albemarle, Indefatigable, James and Duncan Islands.

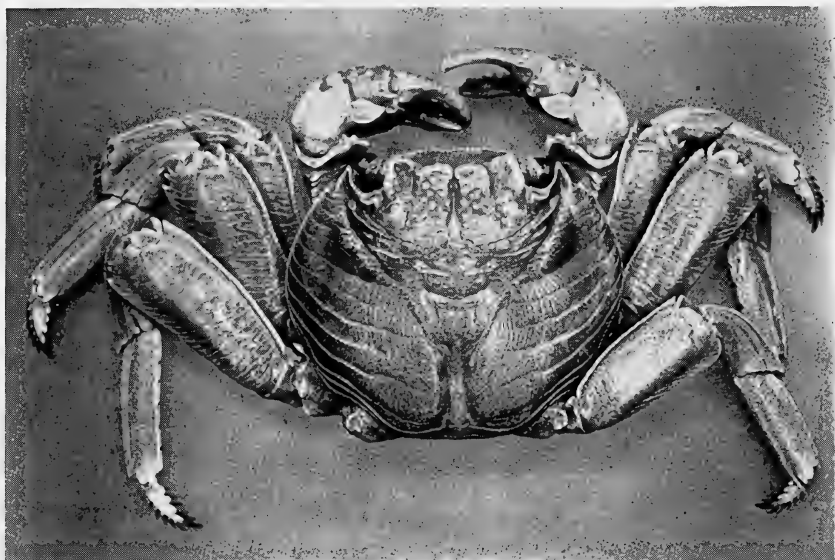


Fig. 90. *Grapsus grapsus*. Reduced to  $\frac{1}{2}$  of natural size.

*General distribution*.—"Sally Lightfoot" is a well-known inhabitant of the tropical and subtropical shores of America from Miami, Florida, southward through the West Indies and Bermudas to Pernambuco, Brazil, on the East Coast, and on the West Coast from San Benito Island, Lower California, southward, including the Galapagos Islands, down to Chile; it is also known from the tropical eastern Atlantic including the Azores and the west coast of Africa.

*Material examined*.—One large male specimen from Hood Island (tag W. B. 817); two large males from South Seymour Island; one adult male and four small young specimens from Station 37, Tower Island, shore zone D to E, April 10, 1923; two young specimens from Station 54, off Hood Island, 15 fathoms, and five young specimens from Cocos Island, were secured by the Arcturus Oceanographic Expedition. Four males from Eden Island, Galapagos, taken by the Harrison Williams Expedition.

*Color*.—Color plates were made by the staff artist, Isabel Cooper, of both the adult and young of *Grapsus grapsus*. Adult male: on the dorsal surface of the carapace, chelipeds and legs, bright scarlet is dominant; the epistome is



light orange yellow touched with scarlet; the pterygostomian region and under-side of carapace are neropalin blue streaked with light orange yellow; parts of the inner and under sides of the basal joints of the legs are neropalin blue; the merus, carpus and part of the propodus are bright scarlet; the distal part of the propodus and dactyl are light orange yellow; the chelipeds have these latter joints vivid scarlet. The eyestalks are yellow; the cornea is violaceous.

*Young—male and female.*—The carapace is chocolate brown striated with light orange yellow and maculated with flecks of neropalin blue. The chelipeds are predominantly neropalin blue basally with the carpus and propodus vivid scarlet, the finger-tips orange. The ambulatory legs have the basal, meral and carpal joints light scarlet maculated with light orange yellow; the propodus reddish-brown; the dactyl, brownish-yellow with black spines. The eyestalks are yellow, the cornea violaceous.

*Habits.*—As long ago as 1725, Hans Sloane observed these *Mardi Gras* dwellers of the rocky shores of Jamaica and noted their abundance, in his "Natural History of Jamaica."

William Beebe, Director of the Arcturus Oceanographic Expedition, who secured the specimens of the present report, has given the following account of *Grapsus grapsus* in his "Galapagos—World's End:"

"As we walked along, hosts of scarlet crabs scuttled away from our path—crabs which we were to know as the most conspicuous and ever-present feature of Galapagos shores. They were old friends and I had seen them years ago in Cuba and Mexico, and scampering over the rocks in St. Thomas and Jamaica. In the latter island they call them Sally Lightfoot, a name much more apt than that by which the carcinologist knows them—*Grapsus grapsus grapsus*,—the old Greek word for crab thrice repeated.

"Catesby writing of the natural history of Florida and the Bahamas one hundred and eighty years ago, gives a vivid paragraph of them in smooth and sonorous English. 'These crabs inhabit the rocks overhanging the sea; they are the nimblest of all other crabs; they run with surprising agility along the upright side of a rock and even under rocks that hang horizontally over the sea; this they are often necessitated to do for escaping the assaults of rapacious birds which pursue them. These crabs, so far as I could observe, never go to land, but frequent mostly those parts of the promontories and islands of rocks in and near the sea, where by the continual and violent agitation of the waves against the rocks they are always wet, continually receiving the spray of the sea, which often washes them into it, but they instantly return to the rock again, not being able to live under water and yet requiring more of that element than any of the crustaceous kinds that are not fish.'

"Nowhere had I ever seen them of so vivid a scarlet as against these sombre lava rocks, and nowhere as abundant. Lying flat on the gentle slope of a huge cube, twenty feet each way, I watched the waving tentacles of anemones far below me. Suddenly a scarlet curtain swept across the whole face of the rock, as an army of crabs skittered into view. Their armour clattered as they ran against or over one another, in their fright they blew strings of little bubbles out of their comic faces and in their haste a number scurried over me. Then came the cause of their fright,—a little bob-tailed, slaty-blue heron, a copy of

our own northern green heron except for the dull, lava-like hues and stouter build, *Butorides sundevalli*. Whether the easy life led by these small herons on the islands has induced corpulency I do not know, but it is a fact that they weight more than two-thirds as much again as their continental relatives.

"My cancrivorous heron watched me suspiciously for a moment, flicking his tail up and down, then dashed at the crabs and seized a leg which its owner promptly discarded. Flying to the top of a neighboring rock, the heron hammered off the terminal joints, crushed the largest and swallowed them. After a short rest the bird made another foray, again secured a stray leg and feasted upon part of it. During coming days I observed this performance on the part of at least four individuals on two islands,—a source of food as certain as it was remarkable, for the discarded limbs are almost always renewed, the crabs being little the worse for the loss of one of their eight feet.

"As Catesby truly says, these crabs never go inland, but are always found within reach of the water, and yet they are indifferent swimmers. This was the first of the many confusing facts with which the Galapagos teemed,—that this species could occur on the Pacific coast with fifty good miles of dry land or equally inimical fresh water between them and their Atlantic fellows, and here seven hundred miles or more away, were thousands forever hurrying about the cooled lava. No change had taken place in their anatomy, although thirty-five millions of years may have elapsed since the Oligocene period when the waters of the Atlantic and Pacific were mingled.

"These hosts of Sally Lightfoots were the most brilliant spots of colour above water in these islands, putting to shame the dull drab hues of the terrestrial organisms and hinting of the glories of colourful animal life beneath the surface of the sea. When such an outburst of crabs occurred as I have described, darting out of all possible and impossible cracks and crevices of the lava, they appeared to the imagination as organic reminders of the sparks and flames which once reddened these great beaches, and these plains and mountains of lava.

"Flying about, close to the precipitous cliffs, just this side of a cave which marked the end of the beach, was a flock of Galapagos purple martins, *Progne subis modesta*. They are smaller than the martins of the mainland and have less white upon their plumage, and have established themselves in small colonies on many of the islands. Darwin observed them on James island, and long before his visit, old buccaneers wrote in their journals of the "swallows" of these islands, birds which took their minds back for a moment to English downs or the eaves of France.

"There were seven birds in sight, one of which was immature, all swooping about and twittering in the usual martin way, and by their fluttering visits to the side of the cliff I located six nests. These were in deep sheltered ledges or in angular tunnels made by the splitting off of the rocks along the weak lines of crystalline deposit. One nest was not more than twenty feet up and by the aid of acrobatic efforts on a long improvised ladder I managed to reach the old bird on her nest, and saw a full-fledged youngster scuttle up a narrow chute out of sight. On my next ascent I was able to dislodge a mass of the cliff which almost buried me as it fell. I just managed to leap out of the way of the hurtling rocks and looking up saw the young fledgling flutter out. It dropped nearly into

my hand, recovered itself and flew with remarkably steady flight out over the jagged summit. I was in time to see the little bird drop exhausted into the water and flap itself ashore, only to be promptly seized by a huge scarlet crab. Holding its prey aloft in the great pincers, the crab climbed the lava slope with others of its bright-hued envious fellows following at a respectful distance. I thought the little swallow had had about enough for one day and I relentlessly pursued the crab and rescued the bird quite unhurt."

\* \* \*

"Our boat grounded gently and we walked up through the colony, the iguanas hardly moving out of our way. For a long time we watched these strange beings, we saw them challenge one another, and pay court to indescribably ugly black lady lizards. And then I saw something which I shall probably mention in another chapter, but it will bear repetition. An iguana about three feet long was resting partly on the sand and partly on a water-smoothed stone, when a large scarlet crab approached slowly, crawled over the whole length of the reptile, and picked off two ticks as it went. If my companions had not been watching at the same time I should hesitate to record such a remarkable occurrence.

"Minute by minute we were ever more impressed by the tame life of the Galapagos, but the crabs were an exception. I could creep close to them but their eyes would watch me closely and they would always slide out of reach, slowly if I approached gently, or like a scarlet flash if I grabbed quickly. Here, however, in this magic cave of Eden there were three crabs which in point of fearlessness might have been the Three Musketeers. When I walked up from the boat one came slowly to meet me, one of the biggest, his carapace fairly aflame in the sunlight. On and on he came, his eyes twiddling comically on their stalks, his thick spoon-shaped claws making queer calabastic signs, intelligible only to the race of *Cancer*. After waving them about regardlessly for a time, he would go through a series of about a dozen motions, absurdly like an American private saluting with both hands at once, the claws being raised to the stalked eyes and brought down simultaneously with a quick jerk. Then followed more irregular signs, and later a quivering as of a drummer's hands beating a tattoo.

"I stood quietly until he came within a foot, then I leaned down, slowly reached out and rubbed his shell. He sank down upon the sand, lowered his eyes into their sockets and wiggled his maxillipeds estatically. I took all manner of liberties, lifting one leg after another, raising him from the ground and replacing him, standing him upon his head, and tapping gently upon his hard back. Surely this must be a very ill crab, or an idiot crustacean, or somehow abnormal. I walked slowly away and to my amazement he turned and followed me. Another crab jointed the first and I felt like a walrus or a carpenter. I took a few steps inland, rounded up a half-dozen ordinarily wary crabs and rushed them in the direction of the tame pair. The stampede was infectious and as I splashed along the water's edge, all fled at full speed. My tame crabs were inextricably mingled with the crowd, and although I tried to stalk them again, they had lost their fearlessness and psychically as well as physically had merged into the mean of the race."

\* \* \*

"I killed a red crab and threw it to my particular quartet (young seals). They dived after it and nosed it but apparently were not yet weaned to such food. In fact I believe that crabs seldom if ever enter into their diet, for these crustaceans show absolutely no fear of the sea-lions, sometimes actually scampering over their sleeping bodies. In the stomach of these we secured I found only remains of fish. The sleek brown animals and the black rocks, the scarlet crabs, the pure emerald of the shallows and the dashing white foam and spray taxed the extreme gamut of colors of our marine artist."

\* \* \*

"Everywhere were the crabs—the same great scarlet fellows, scurrying out of the way of the playful pups, (seals) then following them up without fear. One climbed over the rim of my desk, as the one on Eden had done, and twiddled his stalked eyes at me in a most disconcerting way. These eyes were a rich lavender and his shoulders a deep violet blue, while here and there the scarlet of his back reappeared in small monograms and hieroglyphics—a palimpsest telling more of the past history of *Grapsus* than I shall ever decipher. There must have been five hundred of these crabs in sight, spotting the black lava and pink strata with violent splashes of color.

"At Amblyrhynchus Cove on Eden Island I walked to within four feet of a lizard with my graflex camera. It was half on sand and half on lava and I wished a photograph in just that position as showing the two general types of habitat. As I took the first picture I saw a large red crab approaching on the lava. When I had changed plates, the crab had reached the head of the iguana, and instead of turning aside, crawled straight ahead, the lizard closing its eyes to avoid the sharp legs of the crustacean. On and on the crab went, slowly descending the whole length of the lizard. Three times it stopped and picked a tick from the skin beneath it, the black tissue being tugged high as the crab tugged away. I took another picture as the crab reached the forelegs. I could not see whether the crab even attempted to eat the ticks, but when it had gone on its way over the sand, I put down my camera, crawled forward, caught the lizard, and with my lens found two places where ticks had been. There was no sign of a third having been pulled off, but there were sixteen ticks still remaining on the skin. The whole thing had come as an absolute surprise for while I had several times seen crabs walking on the iguanas, I had not noticed any deliberate attempt to tick catching. These ticks are *Amblyomma darwini* and are closely related to a new species which I discovered on the land lizards."

\* \* \*

"I never saw the iguanas dive for food, and indeed there would seem to be no need for it, for at ordinary times an abundance of the weed was always exposed. As this growth thrived only where there was active surface, so the feeding reptiles were often completely covered, three or four feet deep, by an incoming wave. At such times they and the big scarlet crabs all about gripped tight with their claws and, limpet-like, were immovable. Never did I see one dislodged, and from my experience of trying to drag them out of crevices, I count any such danger as negligible."

*Technical description.*—Carapace discoidal; frontal border vertical, its depth slightly more than half its length; anterior dorsal interorbital surface with a median longitudinal groove which is posteriorly confluent with the mesogastric lines; a submedian notch and its slight posterior sulcus bisect each half of the frontal region. The postorbital tooth is acute; slightly behind it is a second sharp tooth, just anterior to the base of the latter the unusually deep cervical groove arises, proceeds diagonally to the urogastric region and thence runs posteriorly close together outside the cardio-intestinal region. The anterior frontal interorbital region is marked by irregular, transverse rows of low tubercles. There are twelve prominent transverse slightly arcuate ridges, the anterior of which begins at the inner basal angle of the anterolateral tooth and curves across the carapace to near the median dorsal area. All the transverse grooves become vague in the median dorsal region, where the oblique grooves defining the regions of the carapace predominate. The surface of the carapace between the grooves is decidedly reticulated; the subcentral region of the carapace being marked with heavier longitudinal reticulations. There are a pair of depressions at the outer margin of the urogastric region.

The orbits are not quite half as long as the interorbital border, with a distinct notch near the inferior outer angle and a wide inner hiatus which is partly filled by the antennal peduncle, and partly by an isolated tooth. The eyestalks are cylindrical with a distinct median constriction on the outer upper side and a rounded process projecting on the cornea, which is very convex, elliptical, set obliquely terminal.

The antennulae are set nearly transverse in narrow fossae and are partly concealed by the frontal border.

The antennal peduncle partly fills the orbital hiatus and has a conspicuous excretory tubercle on its basal joint; the flagellum is quite small and lies within the orbital hiatus.

The external maxilliped has a tapering rod-like exognath which is two-thirds as long as the endognath and bears an inner, thread-like flagellum about half as long as the basal rod; the ischium of the endognath is subrectangular with its inner margin fringed with setae as long as the merus, the latter being a trifle wider distally than the ischium, and having its inner distal margin depressed; the palp arises from the antero-external angle, and is an unusually large sublobate first joint which fits upon the distal border of the merus, and has its inferior distal margin produced; the second joint is much smaller but distinctly three-sided; the third joint is quite small but thick and armed on its inner surface with a brush of setae. The maxillipeds are set wide apart from each other, showing the mandibles. This space between the maxillipeds at its widest point is one and one-half times as wide as the width of the maxilliped at the distal end of the ischium. The pterygostomian region is finely tomentose.

The abdominal belt consists of seven segments in both sexes; in the male the basal segments are as wide as the sternal plate between the fifth pair of legs. The first pair of male appendages are very stout, extend to midway the sixth segment and have the distal fourth somewhat dilated and are produced at the middle of the distal end into a strong horny tooth, which is dentate at its outer distal angle and rounded distally; the inner distal lateral angle is produced into a

blunt white tooth and armed on its inner and distal surfaces with coarse spiny setae; the outer distal angle is bluntly rounded and armed with similar setae.

The chelipeds (male) have the coxa produced to a tooth-like process at its outer distal angle; the basis is small and fused with the ischium; the latter is produced to a tooth-like process on its distal ventral margin and bears four or more sharp little teeth on its inner ventral margin; the merus is slightly longer than its distal width; three-sided with all three margins denticulate, the inner ventral one most pronouncedly so; the carpus is short, convex and denticulate on its outer margin, with a large lanceolate-acuminate tooth on its inner marginal angle; the propodus is high, subovate, convex on its outer surface, with a sharp flat tooth at the upper distal margin near the propodal finger, with the upper edge of the propodus and half the finger denticulate; below this are several irregular flat tubercles, a longitudinal carina composed of bead-like tubercles runs from the base of the propodus to the inner angle of the propodal finger; a second, similar carina runs almost to the tip of the propodal finger; below this carina a series of ten oblique ridges, the distal of which are bead-like, ornament the lower outer surface of the propodus and lower finger; the fingers are subequal, spoon-shaped at the tip, the lower finger is armed with five teeth along the cutting edge, inside of which are a series of tufts of coarse setae; the upper finger is similarly toothed and tufted. The fingers meet only at the tips.

The ambulatory legs are similar, successively increasing in length posteriorly, the first pair being shorter than the second by the length of almost half the propodus and the dactyl of the latter; the third, fourth and fifth pairs increase in length by less than half the length of the dactyl. All except the first pair have the basal joint produced into a tooth-like process at both its inner and outer distal angles; the basis fused with the ischium, the latter produced to a tooth-like process on the dorsal anterior distal angle, only on the fourth and fifth pairs of legs; all four pairs of legs have the merus conspicuously dorsoventrally compressed, slightly more than twice as long as wide with the frontal margin ridge-like; the distal margin multidentate; the upper surface reticulated by many oblique striae; the carpus is half as long as the merus, very narrow basally and dilated distally, produced to an acuminate point on the anterior distal angle, and longitudinally traversed by a wide groove-like depression and two carinae. The propodus is about as wide but somewhat longer than the carpus, has a distinct longitudinal groove near its anterior margin and a series of spines and bristles on its postlateral margin; the dactyl is very powerful terminating in a strong, claw-like tooth, and armed with four longitudinal rows of strong, tooth-like horny spines, the series successively increasing in size distally.

*Young*.—Specimens 15 mm. in diameter show all the characters of the above described adult which is 90 mm. diameter. They, of course, appear more fragile, and have the different coloration described above.

#### Genus *Geograpsus* Stimpson, 1858

*Geograpsus lividus* (H. Milne Edwards). (Little Rock Crab.)

*Grapsus lividus* Milne Edwards, *Hist. Nat. Crust.*, vol. 2, p. 85, 1837;  
Dana, *U. S. Expl. Exped.*, vol. 13, *Crust. pl.* 1, p. 340, 1852; *atlas*, pl. 21,

- figs. 5 a-c, 1855, Stimpson, *Ann. Lyc. Nat. Hist. New York*, vol. 7, p. 230, 1860.  
*Grapsus brevipes* Milne Edwards, *Ann. Sci. Nat., ser. 3, Zool.*, vol. 20, p. 170 (136), 1853.  
*Geograpsus occidentalis* Stimpson, *Ann. Lyc. Nat. Hist. New York*, vol. 7, p. 230, 1860.  
*Orthograpsus hillii* Kingsley, *Proc. Acad. Nat. Sci. Philadelphia*, p. 194, 1880.  
*Geograpsus lividus* Rathbun, *Bull. 97, U. S. Nat. Mus.*, p. 232, pl. 55, 1917.



Fig. 91. *Geograpsus lividus*,  $\times 1.2$ .

*Diagnostic characters*.—Fingers pointed. Frontal border slightly deflexed; lateral margins clearly delineated.

*Type*.—Prof. Milne Edwards type material came from the Antilles, and is deposited in the Paris Museum.

*Galapagos distribution*.—James, Eden and Hood Islands.

*General distribution*.—On the east American coast this species occurs from the Florida Keys, southward through the West Indies and Bermudas to Sao Paulo, Brazil; it is also known from the Cape Verde Islands. On the West Coast it ranges from La Paz, Lower California to the Galapagos Islands, Peru and Chile. It has also been taken in the Hawaiian Islands.

*Color*.—The color plate made by Isabel Cooper shows the carapace dragon's blood red shading into apricot orange with the margins and striae yellow ochre; maculations of neropaline blue and yellow ochre ornament the carapace and

meral joints of the ambulatories with an occasional few on the carpal joints; the propodal joints are dragon's blood red; the dactyli trend from this color basally toward apricot orange distally. The carpal and propodal joints of the chelipeds are dragon's blood red; the tips of the fingers are vivid yellow ochre. The eyes are fluorite violet.

*Habits.*—This species frequents the same haunts as *Grapsus grapsus* with which it is so frequently confounded in the field, but from which it is at once distinguished by the pointed fingers of the present species as contrasted with spoon-shaped fingers of *Grapsus grapsus*.

In his "Galapagos—World's End" Dr. Beebe gives the following sketch of *Geograpsus lividus*:

My favorite crabs were rich crimson little fellows, the largest not of a penny's diameter, who had no height, only length and breadth. Everything about them was broad and flat and thin as tissue, and it needed all one's attention to catch one, for they could slip between closed fingers and into the merest crack of a crevice, like magic. When cornered, they gave up all attempt at escape and waved their claws valiantly and even rushed forward to attack a finger."

*Technical description.*—Carapace 20.5 mm. long; 24.6 maximum width; moderately convex, subquadrate; frontal border almost straight or a little concave in a dorsal view; four prominent tubercles along the upper part; lateral margins sharply defined throughout its entire length, a little sinuous posteriorly. Dorsal surface covered with fine transverse, granulate striae which are exceedingly faint on the gastric region and absent on the cardiac region.

The chelipeds are moderately subequal in both sexes; the merus has the inner margin expanded, serrated proximally with small teeth, distally with larger ones; the carpus is convex outwardly and has an acute spine at the inner angle; the propodus is moderately developed, convex outwardly; the fingers are subequal, slightly gaping dentate and pointed at the tips. The outer surfaces of the chelipeds is covered with squamiform striae and the upper border of the merus, carpus and propodus are tuberculate.

The ambulatories decrease in length in the following order: second, third, fourth, first. All four pairs have the meral joints quite broad, the maximum breadth being slightly more than half the length of the respective joints; the carpus, propodus and dactylus of each leg is covered with conspicuous, long, slender bristles.

#### Genus *Pachygrapsus* Randall, 1840

##### Key to the Galapagos species of the genus *Pachygrapsus*

- |  |                    |
|--|--------------------|
| A small species. Merus of last ambulatory legs dentate on posterior distal margin. | <i>transversus</i> |
| A large species. Merus of last ambulatory legs smooth on posterior distal margin.  | <i>crassipes</i>   |

##### *Pachygrapsus transversus* (Gibbes). (The Striated *Pachygrapsus*.)

*Grapsus maurus* Lucas, *Explor. Sci. Algerie, Zool. Insectes*, vol. 1, p. 20, and vol. 4 (atlas), pl. 2, fig. 5, 1846.  
*Goniograpsus simplex* Dana, *Proc. Acad. Nat. Sci. Phila.*, vol. 5, p. 249,



1851; *U. S. Expl. Exped.*, vol. 13, *Crust.*, pt. 1, p. 344, 1852; atlas, pl. 21, fig. 8, 1855.  
*Leptograpsus maurus* Milne Edwards, *Ann. Sci. Nat.*, ser. 3, *Zool.*, vol. 20, p. 173 (139) 1853.  
*Pachygrapsus simplex* Stimpson, *Proc. Acad. Nat. Sci. Phila.*, vol. 10, p. 102 (48), 1858.  
*Pachygrapsus maurus* Kingsley, *Proc. Acad. Nat. Sci. Phila.*, p. 199, 1880.  
*Pachygrapsus maurus* Rathbun, *Bull.* 97, *U. S. Nat. Mus.*, p. 244, pl. 60, figs. 1 and 2, 1917.

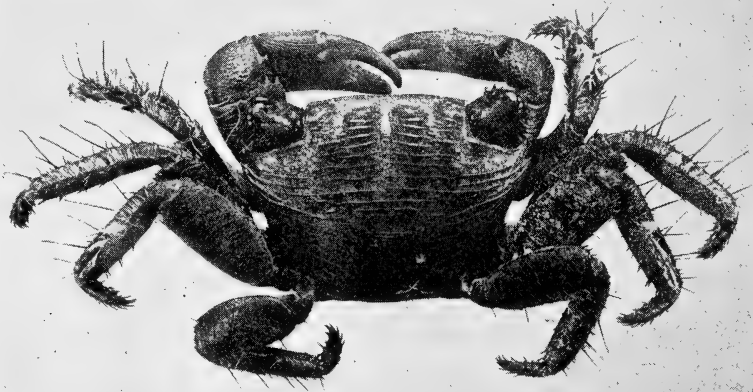


Fig. 92. *Pachygrapsus transversus*,  $\times 3.7$ .

*Diagnostic characters.*—Small species. Interorbital border more than half as wide as carapace, sinuous; lateral margins decidedly convergent; one acute lateral tooth behind the postorbital tooth. Merus of last ambulatory leg dentate on posterior distal margin.

*Type.*—Gibbes' type, which is no longer extant, came from Key West, Florida. However, the types of many of the synonyms of this species are preserved, that of Dana's *Gonigrapsus innotatus* being deposited in the United States National Museum; of Milne Edwards' *Leptograpsus rugulosus*, in the Paris Museum; Saussure's *Metapograpsus dubius* and *Metapograpsus miniatus* are in the Geneva Museum; Heller's *Grapsus declivifrons* and *Pachygrapsus intermedius* are deposited in the Vienna Museum; and cotypes of Stimpson's *Pachygrapsus socius* are in the Museum of Comparative Zoology, Cambridge, Mass.

*Galapagos distribution.*—Chatham and Albemarle, Tower, (*Arcturus* station 37) and Hood (*Arcturus* station 54) Islands.

*General distribution.*—This little species has a rather cosmopolitan distribution in the warm seas, having been recorded from Charlestown, South Carolina, southward along the Florida coasts, the Gulf of Mexico, the Bahamas, Cuba, Jamaica, Porto Rico, St. Thomas, Bermuda, Trinidad, Curacao, Brazil and down as far as Uruguay on the east American coasts. On the Pacific

American coasts it is known from the Gulf of Lower California, Mexico, Costa Rica, Panama, the Galapagos Islands, Cocos Island; and down to Metapalo, Peru.

It is also recorded from the West African coasts. Likewise it is rather abundant in the Oriental region.

*Material examined.*—Three males, two females from Cocos Island; two males and seven females, one of which is ovigerous, from Tower Island; five males and three females from Station 37, shore zone D to E, Tower Island, April 10, 1925. Two males and one female from Station 54, off Hood Island, taken by William Beebe, while diving in 15 feet of water; three males and nine females, one of which is carrying eggs and two more are carrying embryos, from *Sargassum*, taken at Station 3, in the Atlantic Ocean; one female from Atlantic *Sargassum*.

*Habits.*—Although *Pachygrapsus transversus* is most frequently found among the stones, coral rock bottom and sandy shores of the littoral region, it is sometimes taken far out at sea as a dweller in the floating jetsam, *Sargassum*, etc. It was taken along with *Planes minutus* (L.) by the *Arcturus* in the Sargasso Sea, clinging to *Sargassum*. The females of this series were all carrying either eggs or young embryos. One male captured at Tower Island, Galapagos, was eating a cluster of crab eggs which appear to be those of this same species. Miss Rathbun records specimens taken from the bottom of a whaler at Provincetown, Mass. The multispinose setae of the dactyli indicate that such pelagic journeys are normal for the species.

*Eggs.*—A female 9 mm. wide carried 1754 eggs. These were minute creamy white spheres (preserved specimen) being of slightly smaller diameter than the distal width of the outer branch of the egg-supporting appendage.

*Embryos and zoea.*—Another female from the same station showed the developed embryos in which the eyes were tiny dots and segmentation indistinguishable. A second female from this station carried well-developed embryos which were spherical, quite two and a half times as large as the undeveloped egg and which showed clearly the large subspherical black-eyes and the lines of segmentation on the distinctly delineated but folded abdomen. A third female carried zoea breaking through the encasement. It is of interest to note that in all cases the eggs of a female were in a practically identical state of development.

*Technical description.*—Carapace 10 mm. greatest width; 8 mm. long; front deflexed, interorbital space 6 mm. long, margin slightly sinuous and granular; the sides are moderately vaulted and decidedly convergent posteriorly; there is one acute lateral tooth, smaller than and situated just behind the acute post-orbital tooth; the posterior margin is subparallel to and about as wide as the interorbital border. The inferior orbital border is sharply denticulated. The dorsal surface of the carapace is covered with oblique and transverse striae which are granulated and more prominent on the anterior half of the carapace, but are less distinct on the cardiac and intestinal regions; the interspaces between the striae are granulose. The female abdomen is seven-segmented, broadly oval, fringed with setae; the second to fourth segments respectively bear paired biramose appendages to which the eggs are attached. The outer

branch is lamellar, scythe-shaped, tapering distally and fringed with setae; the inner branch consists of a basal article which comprises about two-fifths of its length and is directed inward toward the center, and a distal portion which is composed of seven subequal articles and is directed outward and fringed with very long silky setae. The male abdomen is seven-segmented, narrow, triangulate with the sides of the segments converging anteriorly, the seventh segment being almost an equilateral triangle. The first pair of male appendages are rather stout, decidedly vaulted basally, and moderately spatulate in the distal part of the calcareous rod beyond which there is a thin, flattened, curved, hook-like process of a horny, translucent substance which tapers distally to an outward pointing apex.

The eyestalk is cylindrical, granulose and with a few oblique rugae; it is produced to a small rounded process which projects on the upper surface of the cornea. The cornea is convex and composed of many minute hexagonal facets. It is of about the same diameter as the stalk and extends outward about to the apex of the postorbital spine.

The internal antennae have a large basal article which is fitted into the antennal septum transversely and a slender, elongated, compressed second article; a somewhat shorter and stouter third article which is dilated distally and bears a small four-jointed flagellum and a stouter one consisting of ten tapering articles, which bear a brush of thick setae on the lateral surface.

The external antennae are quite small and are placed in the inner orbital hiatus; the basal article is very short, about four times as wide as long and with the outer side roundly flared; the second article is a trifle longer than the first and is quite bulbous being produced to a convex node on the external side; the third article is less than half the size of the second, being only a trifle longer than the basal flagellum article; the flagellum is of six small articles and reaches to the base of the cornea.

The external maxillipeds are separated from each other by a space almost equal to the width of one maxilliped. The exognath is quite slender, tapers distally on the inner side and bears a palp composed of one long slender basal article and eleven short annulations, the last of which is tipped with a tuft of long setae. The ischium is set obliquely and is wider basally than distally, the inner margin is fringed with setae; the merus is almost three-fifths as long as the ischium and has its outer and distal margins rounded, its inner margin diagonal and carinated with its distal angle produced; the palp has the basal angle flattened, its outer margin convex, its inner recurvate, its distal truncated and supporting the much smaller second joint which in turn bears the little tapering conical distal joint; all three joints are finely setigerous, the distal one being especially so.

The chelipeds are about equally massive in the male and female. The first and second joints are small; the latter is fused with the ischium; the ischium is produced to a point on its anterior distal margin and has its anterior lateral margin tridentate; the merus is three-sided and is produced to a wing-like expansion on its anterior distal part, the anterolateral margin being dentate and the distal margin being cut in three acute teeth on the inner dorsal surface, and produced to one on its posterior ventral distal angle. The carpus is short,

convex dorsally and made rugose by numerous striae and produced to an acute tooth on its inner margin; the propodus is massive being about as long as all the preceding joints taken together and its height is equal to half or slightly more than half its own length; the palm is convex on its outer surface and rather thin on the basal part of its upper margin; the propodal finger is about one-third of the length of the entire propodus and is rather stout, with its distal end narrowly spoon-shaped and tipped with a horn-like substance; the cutting edge is furnished basally with two small and one large tooth followed by five small well developed, triangulate teeth; the lower part of the propodus is longitudinally traversed by a diagonal carina which extends to the tip of the finger; below this carina there are several transverse striae. The hinged finger is slenderer and more curved than the propodal, upon which its horn-tipped apex fits; the cutting edge of the hinged finger is furnished with ten moderate, unequal triangulate teeth which touch, but scarcely interlock with those of the opposing finger. The upper surface of the meral and carpal joints is rugose with transverse and oblique striae.

The first three pairs of ambulatory legs successively increase in length posteriorly, the third pair being the longest; the fourth pair is almost equal in length to the second pair. All have the basal three joints short; the meral joint is broad being about half as wide as it is long, with the dorsal surface transversely striated and the anterior lateral surface set with small spines, one being at the distal angle, the posterior distal margin is cut into three teeth (occasionally only two teeth); the carpus is narrower than the merus and only about half as long, wider distally and with both distal angles acute; the propodus is as wide as the distal part of the carpus and about twice as long; both the carpus and propodus are traversed by two longitudinal striae, the anterior one of which on the first, second and third pair of legs, and the posterior one on the fourth pair of legs, are furnished with fringes of close-set plumose setae; the margins of both these joints are also set with very long spinose setae; the dactyli are about three-fourths as long as the propodi and are quite stout and tipped with a very acute spine and also armed with two dorsal and two ventral marginal rows of stout, sharp spines.

*Pachygrapsus crassipes* Randall. (The large *Pachygrapsus*.)

- Pachygrapsus crassipes* Randall, *Journ. Acad. Sci. Philadelphia*, vol. 8, p. 127, 1839; *De Man, Notes Leyden Mus.*, vol. 12, p. 86, pl. 6, fig. 11, 1890.  
*Grapsus eydouzi* Milne Edwards, *Ann. Sci. Nat. ser. 3, Zool.*, vol. 20, p. 170 (136) 1853.  
*Leptograpsus gonagrus* Milne Edwards, *Ann. Sci. Nat., ser. 3, Zool.*, vol. 20, p. 173 (139), 1853.  
*Pachygrapsus crassipes* Rathbun, *Bull. 97, U. S. Nat. Mus.*, p. 241, pl. 59, 1917.

*Diagnostic characters*.—Carapace with the side very convex anteriorly; one lateral tooth present; striae of dorsal surface quite long. Merus of fifth ambulatory entire of posterior border.

*Type*.—Randall's type-locality is given as Sandwich Islands; the specimen is deposited in the Museum of the Philadelphia Academy of Natural Sciences. (Dr. Rathbun states without explanation that "Sandwich Islands" is probably an error for "California coast.")

*Galapagos distribution*.—Albemarle, Chatham and James Islands.

*General distribution.*—From Oregon to the Gulf of California; also Galapagos Islands, and Cocos Island; Chile; Japan and Korea; Sandwich Islands (type-locality).

*Material examined.*—One female from Cocos Island, May, 1923, taken by the *Arcturus*.

*Color.*—Mottled red-brown with ochreous maculations.

*Technical description.*—Carapace 44 mm. long, 52 mm. wide; interorbital border 24 mm. wide; quadrate, only a little wider than long with lateral regions arched anteriorly, decidedly convergent posteriorly. The postorbital tooth is



Fig. 93. *Pachygrapsus crassipes*. Reduced to 0.6 of natural size.

followed by a smaller tooth. The frontal border is almost half as wide as the carapace with the margin sinuous and the outer angles forming a decided lobe. The orbits are oblique with the upper margins finely granulose, the lower margin denticulate. The buccal cavity is squarish with the anterior angles rounded; there is a rhomboidal space separating the halves of the external maxillipeds. The ischium is longer than the merus; the latter bears the coarse three-jointed palp on its outer anterior border.

The chelipeds are subequal, rather massive, approximately one and three-fourths times as long as the carapace; the merus is finely striated on its upper surface, smooth; its inner margin is produced, the distal margin is dentate; the carpus is also striated and bears a subacute tooth at its inner angle; the propodus is nearly smooth, except for an obliquely longitudinal carina which runs from the proximal end of the propodus to the base of the finger. The fingers are long and gaping.

The ambulatories decrease in length in the following order: second, third, first and fourth pairs; the meral joints of each has a subdistal spine near the anterior border and the three anterior pairs each have several teeth near the distal end on the posterior meral border; this area being devoid of teeth in the fourth pair of legs.

#### Genus *Planes* Leach, 1825

*Planes minutus* (Linnaeus), 1758. (Columbus' Crab; *Sargassum* Crab; Gulf-weed Crab.)

- Cancellus marinus minimus quadratus* Sloane, *Nat. Hist. Jamaica*, vol. 2, p. 270, pl. 245, fig. 1, 1725.  
 "Turtle Crab," Browne, *Hist. Jamaica*, p. 421, pl. 42, fig. 1, 1756.  
*Cancer minutus* Linnaeus, *Syst. Nat. ed. 10*, vol. 1, p. 625, 1758.  
*Cancer pusillus* Fabricius, *Syst. Entom.*, p. 402, 1775.  
*Cancer glaberrimus* Herbst, *Naturg. Krabben u. Krebse*, vol. 1, p. 262, pl. 20, fig. 115, 1790.  
*Pinnotheres minutus* Bosc, *Hist. Nat. Crust.*, vol. 1, p. 244, and X (1801-1802).  
*Pinnotheres pusillus* Bosc, *Hist. Nat. Crust.*, vol. 1, p. 244, and X (1801-1802).  
*Pinnotheres glaberimus* Bosc, *Hist. Nat. Crust.*, vol. 1, p. 244, and X (1801-1802).  
*Grapsus minutus* Latreille, *Hist. Nat. Crust.*, vol. 6, pl. 68, and XI (1802-1803).  
*Grapsus cinereus* Say, *Journ. Acad. Nat. Sci. Phila.*, vol. 1, p. 99, 1817.  
*Grapsus pelagicus* Say, *Journ. Acad. Nat. Sci. Phila.*, vol. 1, p. 41, 1818.  
*Planes clypeatus* Bowdich, *Excursions in Madeira and Porto Santo*, p. 15, pl. 12, figs. 2s and 2b, 1825.  
*Grapsus testudinum* Roux, *Crust. Medit.*, p. (52), pl. 6, figs. 1-6, 1828.  
*Grapsus pelagicus* Roux, *Crust. Medit.*, p. (55), pl. 6, figs. 7-9, 1828.  
*Grapsus* (*Grapsus*) *pusillus* de Haan, *Fauna Japon, Crust.*, p. 59, pl. 16, fig. 2, 1835.  
*Nautilograpsus minutus* Milne Edwards, *Hist. Nat. Crust.*, vol. 2, p. 90, 1837.  
*Grapsus diris* Costa, *Fauna Napoli, Crust.*, pl. 4, fig. 1, 1838.  
*Nautilograpsus major* McLeay, in *Andrew Smith's Zool. South Africa*, *Annul.*, p. 66, 1838.  
*Planes minutus* White, *List. Crust. Brit. Mus.*, p. 42, 1847.  
*Planes linnaeana* Bell, *Brit. Stalk-eyed Crust.*, p. 135, 1851.  
*Planes cyaneus* Dana, *Proc. Acad. Nat. Sci. Phila.*, vol. 5, p. 250, 1851, (issued 1852).  
*Nautilograpsus angustatus* Stimpson, *Proc. Acad. Nat. Sci. Phila.*, vol. 10, p. 103, (49), 1858.  
*Planes minutus* Verrill, *Trans. Connecticut Acad. Arts and Sci.*, vol. 13, p. 325, text-fig. 7, pl. 13, figs. a-j; pl. 27, fig. 6, 1908.  
*Planes minutus* Rathbun, *Bull. 97, U. S. Nat. Mus.*, p. 253, pl. 63, 1917.  
*Planes marinus* Rathbun, *Bull. 97, U. S. Nat. Mus.*, p. 258, pl. 64, 1917.

**Diagnostic characters.**—Carapace squarish, uniformly convex, button-like. Color pattern a mimicry of seaweed. The power of changing its coloration in imitation of that of its surroundings is the outstanding field-character of this species.

**Type.**—Linnaeus' type-locality is given; "*In Palagi Fuco natante.*" His type specimen is, unfortunately, no longer extant.

**Galapagos distribution.**—On green turtle, off Galapagos (Rathbun); *Arc-turus* station 54, off Hood Island (Beebe).

**General distribution.**—This quaint "little wanderer" of the tropical and subtropical areas of both the Atlantic and Pacific Oceans is perhaps the oldest recorded crab of the new world, for, as stated by Hans Sloane (1705): "Columbus on finding this alive on Sargaffo floating in the Sea, concluded himself not far from fome land in the firft voyage he made on the difcovery of the Weft Indies." It occurs most abundantly in gulfweed, especially in the Sargasso Sea and is

occasionally found on turtles, floating logs and debris and large jellyfishes. It is sometimes found along the shore lines after severe storms.

*Material examined.*—An extensive series of specimens of this species representing practically all stages of development from egg to adult were secured by the Arcturus Oceanographic Expedition:

Two hundred small adults, about 50 per cent. of the females carrying eggs; females 5 mm. wide, were heavily laden with eggs; from Gulfweed, Atlantic Ocean, March 4, 1925.

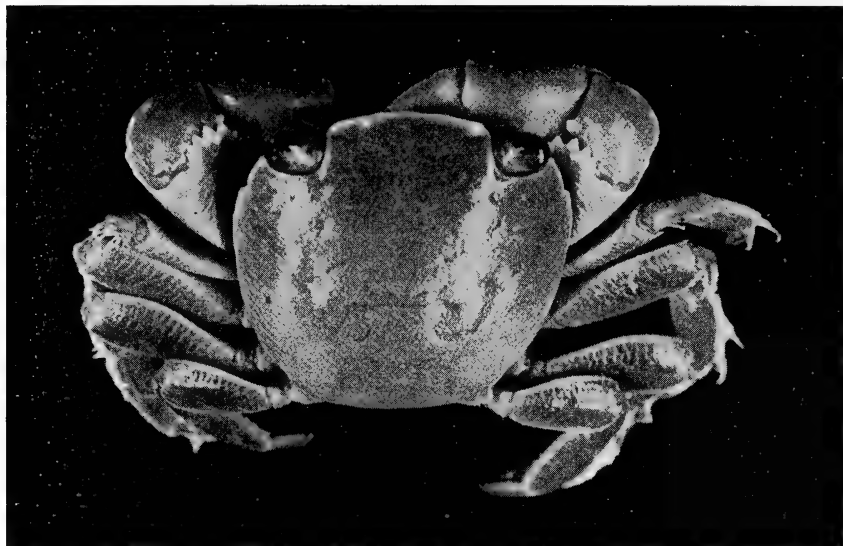


Fig. 94. *Planes minutus*,  $\times 3$ .

Thirty-seven specimens somewhat larger than the above series, many of the females with eggs, from *Sargassum* weed, Atlantic Ocean, March 7, 1925.

Thirty-six specimens from *Sargassum*, Atlantic Ocean.

About seventy-five specimens, some with eggs from *Sargassum*, Sargasso Sea, Lat. 25 degrees 56 minutes N., Long. 55 degrees 42 minutes W.

Thirty-six specimens from *Sargassum*, Sargasso Sea, February, 1925.

Fifty-six adults from *Sargassum* near the Sargasso Sea, February 20, 1925; most of this series were very small adults, some with eggs.

Twelve small adults from *Sargassum*, Atlantic Ocean, February 21, 1925.

Six young adults, from Station 5 Sargasso Sea, Lat. 26 degrees 42 minutes N., Longitude 52 degrees 59 minutes W., on *Sargassum* February 11, 1925. (Color plate of these specimens was made by Isabel Cooper.)

Seventeen specimens, including two very large males, from floating log, Station 74, sixty miles south of Cocos Island, Pacific Ocean.

Four males, including one very large specimen from the tide rip, Station 31,

Pacific Ocean (tag W.B. 802). Color plate of these specimens was made by Isabel Cooper.

Four very large specimens, three males and one ovigerous female, were obtained from the surface at Station 31; one male and one female specimen bear young goose barnacles attached to their carapaces. The ovigerous female is carrying zoea about ready to escape from the test. These zoea measure 0.6 mm. diameter.

One male and two females from station 54, off Hood Island.

*Color.*—A series of five sketches was made by the staff artist, Isabel Cooper, showing the range of color variation of which this unusual little crab is capable. In sketch No. 1 the ground color of the carapace and appendages is pale light salmon mottled with light pinkish cinnamon, the legs being banded with this color; a large subovate whitish area occupies the anterior half of the carapace. In sketch No. 2, the design is the same as in No. 1, but instead of salmon the ground-color is tawny-olive and the mottlings a light vinaceous brown. In No. 3 the design is the same as in Nos. 1 and 2 but the ground color is light yellowish olive mottled with brownish olive. In No. 4 there is no large white area on the carapace, the ground color is very pale salmon mottled and banded with gull grey; the carapace is flecked with minute vinaceous brown spots, and the chelipeds and distal half of the ambulatory legs is light ochraceous salmon. In No. 5 the design is similar to that of No. 4 but the ground color is tawny olive and the mottlings are vinaceous brown and the chelae are light ochraceous salmon.

*Technical description.*—Carapace ovate-quadrate usually about as wide as long, decidedly convex, surface usually smooth, with the regions scarcely indicated in small to medium-sized specimens but in several specimens of 20 mm. or more in diameter, the branchial, mesogastric, urogastric, cardiac and intestinal regions are distinctly delineated, the anterior gastric region is deeply bilobed and the lateral tooth is emphasized, while the transverse lines on the branchial region are unusually prominent. The inteorbital space is half or more than half the width of the carapace; the frontal border is relatively straight, the orbit is oval, a little oblique with the postlateral angle sharp, the inferior border straight, with a deep inner hiatus which is partially filled by an isolated tooth and the basal antennal article. The eyestalk is cylindrical, slightly swollen basally, and with a shallow constriction on its outer upper median surface, and with a small rounded process on the upper surface of the cornea; the cornea is placed obliquely on the outer distal end of the stalk and is a deep dark brown color.

The antennulae are nearly transverse, and have the basal article long, cylindrical, the second article slightly shorter and dilated distally, the stouter branch of the flagellum composed of twelve conically tapering articles that bear a brush of setae on the outer margin; the slenderer branch composed of eight articles each of which bears two short setae on its distal margin.

The antennae have the basal article outwardly convex and wider than long, the second article with both lateral margins produced, rounded and fringed with setae; the third article narrow, cylindrical supporting a small flagellum base which bears six subequal, tapering articles.



The epistome is well-developed.

The external maxillipeds are set wide apart, the gap being nearly as wide as the ischium of the endognath. The exognath has a distally tapering rod that reaches to about midway the merus and bears a long, slender palp consisting of a slender basal article and about twelve annulations. The ischium of the endognath is elongate, cleaver-shaped, with the inner margin slightly rounded and finely setigerous; the merus is two-thirds as long as the ischium and much wider with its lateral borders roundly produced and its distal border excavate in the median area for the reception of the palp; the latter has the basal joint quite dilated distally; the second and third joints subequal in length, quite fleshy, the latter tapering distally with its margins heavily setigerous as on the margins of the merus.

The male abdominal belt consists of seven segments which taper to a tri-angulate apex distally; the basal segments are as wide between the fifth pairs of legs as the sternal plate. The first to seventh segments successively increase in length distally, the sixth and seventh segments being conspicuously wider than the preceding series. The first pair of male abdominal appendages arise from a strong, vaulted, archlike base and consist of a pair of very strong, stout, club-like processes that reach forward to the fourth from front sternal plate, whose sidewalls have a concave depression fringed with setae, into which the tip of the process fits; there is a prominent rounded tubercle on the outer posterior margin of the cavity of the third sternal plate, just in front of the tip of the genital appendage. The appendage is bluntly rounded at the distal end but bears on the outer distal margin a spoon-like corneous process which has its concavity on the outer posterior side and its convex surface covered with brushlike setae.

The female abdomen is seven-segmented, broadly rounded, covering the entire sternal plate between all the respective pairs of legs, and anteriorly reaching forward to the base of the maxillipeds. This abdomen is strongly convex, and has its entire margin heavily fringed with setae. The second to fifth segments inclusive bear the four pairs of female abdominal appendages. These are similar and subequal, consisting of a very brief basal article, a long curved outer branch, fringed with rather short plumose setae, and a two-jointed inner branch whose proximal article is directed diagonally toward the center and whose distal part consists of the subequal articulations each of which bears at its distal margin a cluster of exceedingly long nonplumose setae, which form a limb that lies along the median line of the cavity. The round genital apertures of the female are in the fourth from front sternal plate which lies between the second pair of ambulatory legs. A female measuring 5.2 mm. diameter carried 2268 eggs in her pouch. (I am indebted to Mr. Serge Chetyrkin for painstakingly counting these eggs.)

The chelipeds are equal, those of the female are well-developed but those of a male of equal diameter are distinctly more massive than those of the female. The coxal, basal and ischial joints are short, the merus is three-sided, dilated distally, with its anterior ventral margin finely serrate and this distal angle strongly quadridentate; the carpus is convex on the upper surface, with a pronounced acuminate tooth on the inner lateral margin. The propodus is longer

than the combined length of the merus and carpus, has the palm high, depressed cylindrical, with the outer surface convex and finely punctate; the propodal finger is short, obtuse, with the tip narrowly spoon-like, the inner margin with two very large teeth midway its length, flanked by two small teeth basally and four distally; inside these teeth there is a row of sensory setae. The upper finger is set semi-obliquely and is more curved and tapering than the lower, and has a similar rounded tip; the cutting edge is set with a very large basal tooth, followed by four fairly large and eight small teeth.

The ambulatories are similar; the first pair is slightly shorter than the second and third pairs which are about equal, while the fourth pair only reaches midway the propodus of the third. All have the basal joints short, the merus, carpus and propodus approximately half, or in places more than half, as wide as long; there is a subdistal tooth on the anterior margin of the merus and the dorsal surface of the latter is striated with transverse ridges, and has its posterior distal margin and armed with several (usually three or four) sharp teeth, those on the second and third legs usually but not invariably stronger than those of the fourth and fifth legs. The anterior margin of the carpus and propodus is fringed with close-set plumose setae and the posterior margin of the propodus is armed with two rows of alternately set spines; the dactyl is quite stout with its anterior margin rounded distally and the apex tipped with strong spines; there are two rows of spines on the anterior lateral margin and two similar rows on the posterior lateral margin of each dactyl; there are setae interspersed with these spines.

The extensive series of *Planes minutus* (Linnaeus) obtained by the Arcturus Oceanographic Expedition show in varying degree some or, occasionally, all of the distinguishing specific characters of *Planes marinus* Rathbun. A critical comparison of the type of this species, with the Arcturus material from both the Atlantic (Sargasso Sea) and the Pacific Ocean show conclusively that *Planes marinus* is merely an unfixed variation within the species *Planes minutus*.

The "broader carapace" ascribed to *Planus marinus* is not borne out by measurement of the type which is quite within Miss Rathbun's own diagnosis of *Planes minutes*, "the carapace varies from a little longer than broad to a little broader than long," a point repeatedly illustrated by the Arcturus collection. The "carapace depressed about the middle" is scarcely to be accepted as a specific character, since in the three specimens of *Planus marinus* it may be due to some shrinkage in the preserved specimens, or to the age of the specimens, for in *Planes minutes*, as in *Grapsus grapsus*, there is a marked increase of sculpturing in the older specimens. Also the factor of ecdysis must be considered. Hundreds of *Planes minutus* which I have had moult in my laboratory aquaria at Miami, Florida, have cast shells deeply grooved for the species, and emerged with an ungrooved soft shell. The physical condition of the crab and its consequent capacity to produce a rapid increase in size and a heavily calcareous shell were evidently factors affecting the appearance of the carapace.

The "nearly straight" posteriolateral margins ascribed to *Planes marinus* are, unfortunately, not apparent in Miss Rathbun's illustration of this species, nor discernible in the type itself when the latter is compared with a large series of *Planus minutes* for the latter show considerable variation in this respect.

Several specimens, with the carapace narrower than long, and devoid of median depressions have a posterolateral margin which is more nearly straight than that of the type of *marinus*.

The "broader basal joint of the antennae and broader merus joint of the outer maxilliped, both its inner and outer lobes being more strongly developed" cited by Miss Rathbun, are usual but not invariable characters of all the large old *Planes minutus* in the present collection; they are as frequent in specimens longer than wide as in those wider than long. Some have these characters combined with an extremely arcuate postlateral margin.

The "feebler dentition of the distal end of the inner expansion of the arm" is too variable to merit serious discussion. It is not infrequently found on one arm, while the opposite arm will present a decided dentition. Sometimes in old specimens of both sexes this dentition is much worn down. Often in regenerated limbs it is decidedly feebler.

### Subfamily: PLAGUSIINAE

#### Genus *Plagusia* Latreille

*Plagusia immaculata* Lamarck. (Pacific Log-rider.)

*Plagusia immaculata* Lamarck, *Hist. Anim. Sans Vert.*, vol. 5, p. 247, 1818; Miers, *Ann. Mag. Nat. Hist.*, ser. 5, vol. 7, p. 150, 1878; *Challenger Rept. Zool.*, vol. 17, p. 273, pl. 22, fig. 1, 1886; Rathbun *Bull.* 97, U. S. Nat. Mus., p. 335, pl. 103, 1917.  
*Plagusia tuberculata* Rathbun (not Lamarck) *Proc. U. S. Nat. Mus.*, vol. 21, p. 605, 1898.

*Diagnostic characters*.—Tubercles of carapace depressed, subsquamose.

*Type*.—Lamarck's type-locality is given as: "la Mediterranae Je la crois de l'Ocean Indien." The type is deposited in the Paris Museum.

*Galapagos distribution*.—*Arcturus* station 54, off Hood Island, appears to be the first Galapagan record of this pelagic species.

*General distribution*.—As long ago as 1818, this species was recorded from the Indian Ocean. Its range was greatly extended in the Indo-Pacific region by the explorations of the Challenger Expedition. More recent findings of the United States government agents and private collectors have established the distribution of *Plagusia immaculata* along the west American coast from Costa Rica to Panama.

*Material examined*.—One ovigerous female, one male from Station 74, from floating log. Four large ovigerous females, four small females, one large male and six small males from the tide-rip, Station 31. Two ovigerous females from driftwood, Cocos Island; one of these is a very large specimen. The smaller of these Cocos specimens carried 17,300 eggs. (Counted by Mr. Serge Chetyrkin). Two young specimens from Station 54, off Hood Island.

*Habits, color*.—This fearless little mariner of the tropical Pacific spends much of its life on the floating jetsam of the ocean although it has also been recorded occasionally from specimens captured along the rocks at high tide where they probably were beached. Although *Plagusia immaculata* is an excellent swimmer it is better known as "log-rider." Its color pattern of dark vinaceous brown mottled with deep sea-foam green, a pattern so designed that it simulates the color scheme of the dull decaying log splashed by spray, renders

the little crab relatively indistinguishable from its environment. This illusion is further enhanced by the posterior margin of the legs being heavily fringed with sea-green hairs which resemble the tufts of algae and bryozoa found on floating

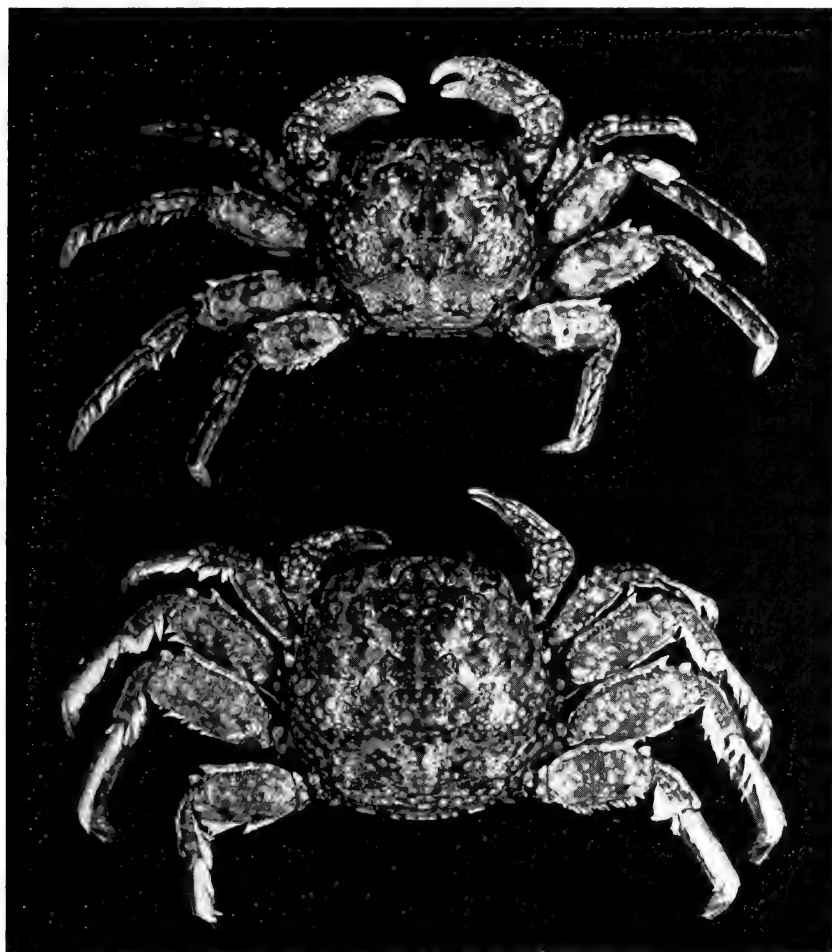


Fig. 95. *Plagusia immaculata*, upper figure female; lower figure male, natural size.

logs. The merus of the legs is flattened dorso-ventrally and armed with teeth distally, while the slender carpus, propodus and spinose dactylus are deflected, forming an effective device for holding on to the pelagic homes.

Although this species was discovered as long ago as 1818, the interesting

habits of this little crab were ignored or entombed in misleading language until the present year when William Beebe published the following notes in his "Arcturus Adventure," p. 49, 1926 (Putnam, New York City): "I was afraid that all the small folk in the wooden sanctuary must have fallen out from the shaking and the banging to which the log had been subjected; but little did I know the clinging powers of these small beings. In the case of this particular log they might have all come of the race of Jumblies. . . . Crabs in multitudes crept about or were picked out of crevices and waterworn cracks. Some were pale olive gray, irregularly mottled with maroon, looking like bright-colored conglomerate rocks. On the legs were sea-green swimming fringes. The ivory white underparts never showed, as the crabs always scurried about with bodies held close to their pelagic island. Some of the forward-bent abdomens were cupped about a large mass of chocolate spawn."

*Technical description.*—Carapace subcircular, very convex, feebly tuberculate; tubercles not fringed with setae; all the regions of the carapace are distinct. There is a pair of small, submedian rostral teeth and four sharply defined subequal teeth on each anterolateral margin (including the orbital tooth). Eight low squamose tubercles are in a subcrescentic formation on the anterior part of the gastric region. In small specimens, (about 20 mm. long), these tubercles are relatively invisible, but in older specimens, (about 36 mm. long), they are very evident. The epistome is prominent, extending ridge-like beyond the anterior border of the carapace, divided into five lobes, the submedian pair being finely crenulate.

The abdominal belt of the male is triangular with rounded apex; it consists of seven segments; segments one and two articulate as a unit, as also do segments three, four, five and six; the last segment swings on a very flexible hinge. The female abdominal belt covers the entire sternum except a slight margin of the plate between the chelipeds, and is very convex externally, and concave internally, forming a pouch in which the eggs are carried. The first and second segments articulate as a unit, as do the third, fourth, fifth, sixth and seventh; the entire free margin of the belt is fringed with setae; the margin of the ventral surface of the crab in the semicircle extending from the base of the second ambulatory legs forward, is also fringed with close-set fine hairs, their density increasing in the median area. The abdominal appendages are setose.

The male chelipeds are massive, the hand and finger together being almost as long as the carapace; very convex on the outer surface; three-fifths as broad as long, covered except near the apex of the fingers by rounded tubercles which near the upper margin are stronger, and are arranged in distinct longitudinal rows. The distal margins of the carpus and merus are multispinose. The inner margin of the meral, carpal and propodal joints of the male cheliped have tufts of strong, irregularly spaced brush-like setae which face the finely and sparsely setigerous under parts of the carapace. The chelipeds of a female of about the same size as the above-described male are small, weak; the hand and fingers together being equal to only half the length of the carapace, scarcely one-third as wide as long, practically devoid of tubercles and finely reticulate. The ambulatory legs are very powerful, about the same size in both sexes, the merus is well-developed, approximately half as broad as long, dorsally flattened

and keeled, has a large spine near the distal margin and the distal margin itself is broken into several short spines; the carpus and propodus are slender, the carpus being two-thirds as long as the propodus which is about as long as the merus; the dactyl is stout, terminates in a very stout spine and has a longitudinal row of five spines on the inner margin. There is a long fringe of sea-green setae on the posterior margin of the legs, thin on the merus but long and heavy on the carpus, propodus and dactyl, resembling algae on driftwood. Occasionally on large, (36 mm. wide), specimens of both sexes there is a weak thin fringe of much shorter hairs on the anterior margin along the groove of the same segments.

**Family: OCYPODIDAE**

**Subfamily: OCYPODINAE**

**Genus *Ocypode* Fabricius, 1798**

*Ocypode gaudichaudii* Milne Edwards and Lucas, 1843.

*Ocypode gaudichaudii* Milne Edwards and Lucas, *d'Orbigny's Voy. dans l'Amer. Merid.*, vol. 6, 1843, *Crust.*, p. 26, vol. 9, *atlas*, pl. 17, figs. 4-4b, 1847; Rathbun, *Bull. 97, U. S. Nat. Mus.*, p. 373, pl. 129, fig. 1, pl. 130, pl. 1, 1917; *Zoologica*, N. Y. Zool. Soc., vol. 5, no. 14, p. 155, pl. 7, figs. 1-3, 1924.

**Name:** Dr. Robert E. Coker states that this crab is known in Peru as the "carreto" or cart-driver. It is also known as the west coast "beach crab" and "ghost crab."

**Diagnostic characters.**—Fingers truncated. Eyestalks produced to a point beyond the eyes.

**Type.**—The type material of this species came from Chile and is deposited in the Paris Museum.

**Galapagos distribution.**—Chatham Island (*Albatross*); South Seymour Island (*Arcturus*) Eden Island (megalops; Harrison Williams Expedition); Black Bight, Albemarle Island (Hopkins-Stanford Expedition).

**General distribution.**—This species is known from San Pablo, California, southward including the Galapagos Islands, to Valparaiso, Chile. Cano has recorded it from Honolulu.

**Material examined.**—Three females were obtained at South Seymour Island, Galapagos, by the *Arcturus* Oceanographic Expedition; one megalops from puffer, Eden Island (Harrison Williams Expedition).

**Habits.**—The species follows practically the same mode of life as its close relative, *Ocypode albicans*.

**Technical description.**—Carapace rectangular, moderately convex, frontal border sinuous, with anterolateral angles prominent, almost right-angled; lateral margins a trifle arcuate anteriorly, convergent posteriorly. Width at anterolateral angles 35 mm., length at median dorsal line 30 mm., interorbital space 4 mm. wide. The sidewalls of the carapace are high and prominent, being tumid anteriorly, slightly concave above the base of the second leg and with the posterolateral region outlined by a bifurcation of the lateral margin which forms a triangulate area. The posterior margin is decidedly arcuate. The superior orbital border is excavate at the inner angle for the reception of the eyestalk then produced into a rounded lobe fitting the constriction of the stalk, then

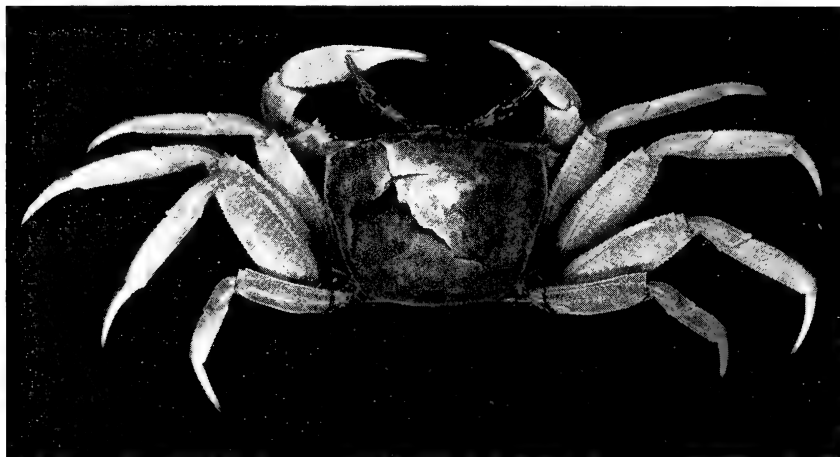


Fig. 96A. *Ocypode gaudichaudii*, adult. Reduced to  $\frac{6}{7}$  of natural size.

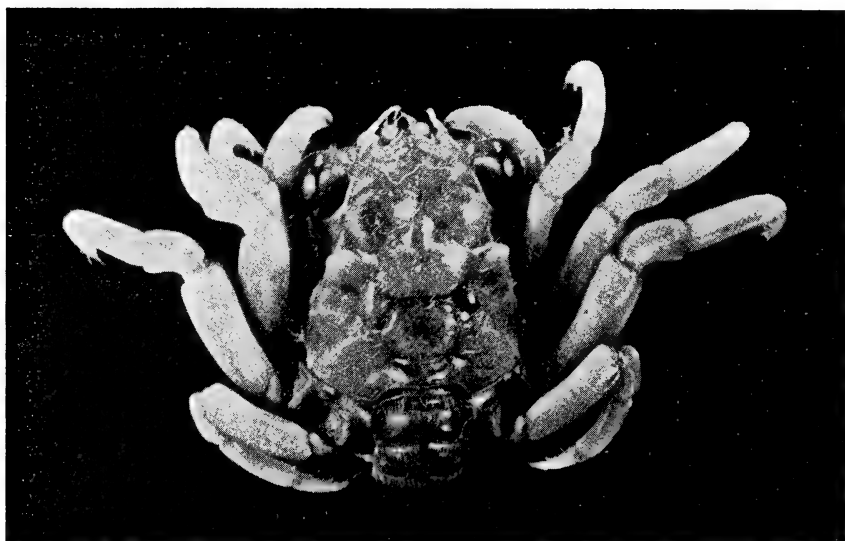


Fig. 96B. *Ocypode gaudichaudii*, megalops, enlarged  $\times 7$ .

sloping backward, the outer angle being almost right-angled. The outer inferior margin of the orbit is excavated to accommodate the style of the eyestalk; there is a deep notch approximately midway the lower margin and there is a short sharp tooth inset near the base of the eyestalk. The upper and lower margins of the orbit are finely serrate. The ventral region is strongly convex. The abdominal belt of the female is broadly oval. The first segment is very short and extremely narrow, the second and third segments are subequal in length each being about one-third longer than the first segment; the fourth segment is about a third longer than the third; the fifth is about a third longer than the fourth; the sixth, which is the longest of the series, is about one-third longer than the fifth and has its anterolateral angles roundly produced; the seventh segment is very small, set in the middle of the anterior border of the sixth, and has its anterolateral borders rounded. The apex reaches the anterior border of the first sternal plate. There are four pairs of biramose abdominal appendages, similar in structure to those of *Ocypode albicans*, borne by the second to fourth segments respectively.

The eyestalk is cylindrical, constricted near the base of the cornea but produced along the dorsal surface separating the edges of the cornea, and beyond the distal end of the cornea forming a slender cylindrical, slightly up-and-outward ovoid; the cornea is elongate-ovoid, the corneal area on the dorsal surface being scarcely half as long as that on the outer and ventral surfaces; the dorsal edges of the cornea being separated by the produced stalk.

The antennulae have the basal article which contains the auditory organ, very tumid, closely fitted into the cavity on each side of the median frontal "tongue" which partly conceals the basal and entirely conceals the remaining joints of the antennulae, which are rudimentary and consist of two short subequal articles of about the diameter of an ordinary sewing-needle, and a stubby, round knob representing the stouter branch of the flagellum and two minute slender articles representing the slender branch of the flagellum.

The antennae have the basal article decidedly bent upon its proximal portion and lodged with the minimum of flexibility in the space between the antennulae and the orbital sinus; the second joint, which is almost squarish with its outer surface convex, and is a little bent inward distally, differs in shape and proportion from that of *Ocypode albicans*; the third joint is small, cylindrical and directed outward and supports the tapering eleven-jointed flagellum which scarcely reaches the apex of the isolated tooth near the inner lower orbital angle.

The external maxillipeds are slightly larger in proportion to the rest of the animal, than are those of *Ocypode albicans* and they are also more strongly vaulted and protruding than those of *Ocypode albicans*. The exognath is a simple rod without palp which reaches only to the base of the merus; the ischium of the endognath is broad, rectangular, with its inner margin decidedly setigerous and almost touching; the merus is only half as long as the ischium and is only about two-thirds as wide distally as it is proximally with its distal margin truncated and its inner margin raised in a conspicuous ridge; the palp arises from the outer distal angle of the merus and fits across the distal border of the merus, having its distal portion dilated; the second article is only half the length of the merus but is swollen club-like, the third joint is cylindrical, quite slender,



fringed with setae, tapering to a blunt point which reaches almost to the middle of the ischium.

The chelipeds are unequal in both sexes, but are similar in structure. The three basal joints are small. The merus is three-sided, one margin being posterior and two anterior; both of the latter are denticulate, the upper one being especially so and produced to a dentate point distally; the carpus is short, convex on its outer surface with both the upper and lower distal marginal angles produced to a tooth; the palm is high and flattened, its outer surface a little convex and covered with coarse squamosities; the width of the propodus is equal to its length from base to beginning of the finger, which is approximately as long as the palm. The stridulating ridge which runs across the distal inner surface of the palm is composed of about seventeen tubercles on the upper half and forty-five striae on the lower half; it plays across a smooth complementary ridge which longitudinally traverses the distal half of the anterior surface of the ischium. The upper and lower margins of the propodus including that of the propodal finger, and the proximal half of the hinged finger, are quite serrate. The fingers are high and flat and decidedly truncated at the tip with the inner angle forming a little tooth; the propodal finger is somewhat broader than the hinged; and is longitudinally traversed by two carinae composed of slightly larger squamosities than those on the remaining surface; a similar, single carina traverses the upper finger; both fingers are continuously denticulate along the cutting edges which meet throughout their entire length.

The ambulatory legs are long, slender and similar in structure. The second pair is the longest of the series, exceeding the length of the first pair by about two-fifths of the length of its dactyl, and likewise exceeding the third pair by one-fifth the length of its dactyl; the fourth pair of legs is conspicuously shorter and only reaches halfway the length of the propodus of the third pair. All have the basal three joints small; the meral joint the longest of the series, being approximately as long as the carapace is wide or high, and in the second, third and fourth meral joints, especially the third, their greatest width is approximately one-half their length; the carpus is about one-half as long as the merus, quite narrow basally, moderately dilated distally; the propodus is three-fourths as long as the merus, is quite narrow, depressed cylindrical, traversed on its upper side by a longitudinal carina, slightly posterior to the median line; the dactyl is about as long as the propodus and is very slender, slightly curved, tapering to an acuminate point. The merus, carpus and propodus are laterally compressed but the dactyl is dorsoventrally flattened, more conspicuously so distally. The merus has the anterior edge carinate and finely serrate and the posterior margin finely serrate also; there is a transverse constriction on the upper side just behind the distal border of the merus; the upper meral surface is distinctly reticulated and sparsely ornamented with squamose tubercles; the carpus is subquadrate in cross-section, the paired dorsal edges are coarsely serrate or denticulate and the surfaces of the carpus are covered with rough squamosities; the upper distal angle of the carpus is produced into a tooth-like process which bears two rows of about four denticles each; the propodus also is covered with rough squamosities which are more prominent along the dorsal border; there is a line of fine setae along the longitudinal groove of this segment

on the upper dorsal surface of the distal end there is a patch consisting of fine spinose setae; the dactyl has the dorsal surface between the two carinated dorsal margins filled with similar spinose setae, below the dorsal carinae; the ventral surface is fluted with three or four carinae which extend nearly to the tip and which have short setae in the depressions between them; the tips are flattened dorsoventrally and very acuminate.

The following is Miss Rathbun's description of the megalops:

"A small crab was taken from the surface of a puffer, *Spheroides annulatus*, in a pool at Eden Island. It proved to be a megalops, or one of the later developmental stages of a crab; it is similar to a known megalops of *Ocypode albicans*, and for that reason I have ventured to give it the name of the only sand crab occurring at the Galapagos, viz.: *O. gaudichaudii*. In the adult of this species the eyes are remarkable in having a slender style projecting from them; this style may be as long as the eye and its stalk.

The carapace of the megalops is 4.6 mm. long, 4 mm. wide. Its sides are high and are crossed obliquely by three furrows into which as many ambulatories may fit; between the first (or anterior) and the second groove, there is a prominent, rectangular, hepatic tubercle; on the branchial region on the posterior margin of the second groove there is a sharp oblique ridge. The mesogastric and cardiac regions are each set off by deep grooves; the mesogastric is partially divided into three parts. The front is deeply cut into three narrow, deflexed lobes, of which the lateral are only half as long as the median lobe. A deep median groove extends forward from the gastric region. The body is covered with pigment spots which are larger anteriorly and diminish in size and number posteriorly, being very few on the sixth abdominal somite and absent from the telson. The raised portions of the carapace are covered with a short pubescence, while a transverse line of hairs crosses the branchial and anterior cardiac regions. The posterior border of the first six abdominal somites is fringed with short hair, and of the pleopods with long hair.

The ambulatories are sparingly dotted with fine pigment spots which thin out distally, being absent from the dactyl and upper half of the propodites. Five spines below each dactyl, the second spine from the tip being the longest. No hairs between bases of second and third ambulatories."

Genus *Uca* Leach, 1814.

Key to the Galapagos species of the genus *Uca*.

Anterolateral angles of carapace almost right angles, but with the corner produced slightly forward. Orbital margin moderately oblique.

*galapagensis*

Anterolateral angles of carapace retreating. Orbital margin pronouncedly oblique.

*helleri*

*Uca galapagensis* Rathbun.

*Uca galapagensis* Rathbun, *Proc. Washington Acad. Sci.*, vol. 4, p. 275, pl. 12, figs. 1 and 2, 1902; *Bull.* 97, *U. S. Nat. Mus.*, p. 403, pl. 142, and text fig. 167, 1917; *Zoologica*, *N. Y. Zool. Soc.*, vol. 5, no. 14, p. 155, 1924.

The odd aspect of this group of crabs, resulting from the strikingly dis-



Fig. 97. *Uca galapagensis*, upper figure male; lower figure female,  $\times 1.8$ .

proportionate size attained by one of the claws in the male and the curious manner in which the little creatures handle this claw, has been a source of comment among the peoples of many lands, which has found expression in a series of quaint common names. Among English-speaking folk, it is known as the "calling crab" because it seems to be forever beckoning with its huge claws. Another name, and the one by the way, most widely used along the coasts of the southern United States is "fiddler" crab, from the fancied resemblance of this great claw to this musical instrument.

The Japanese have woven a legend around the species of *Uca* common in Japan, and give it the name *Siho maneki*, which means "beckoning for the return of the tide." Linnaeus and Latreille have both indirectly referred to this habit of the little crab, in giving it scientific names. To the Peruvians these crabs are known as "*maestro-sastre*," (master-tailor). Long before the coming of Columbus to the New World, these little crabs were woven in the folk-lore of the Indians who dwelt along the coast. Since the present species falls within that group of the genus characterized by a broad front, Miss Rathbun has designated *galapagensis* as "broad fronted fiddler" crab, a name which seems not especially fortunate in view of the fact that it is equally applicable to several species, one of which is the other Galapagan fiddler, *Uca helleri*.

*Diagnostic characters.*—Distinguished from the other Galapagan fiddler by having its anterolateral angles almost right-angled, but with the corner produced slightly forward, whereas in *Uca helleri* this angle is slightly retreating. The orbital margin is oblique but less so than in *helleri*. The oblique ridge inside the palm is continued to the upper margin, in both *galapagensis* and *helleri*, but this item serves to distinguish them from several other species; as does the fact that both species have the merus of the ambulatory legs enlarged.

*Type.*—The type-material (six male specimens) was taken by the United States Bureau of Fisheries Steamer *Albatross*, at Indefatigable Island, Galapagos Islands, April 12, 1888, which fact was seemingly overlooked fourteen years until the Hopkins-Stanford Galapagos Expedition secured nine specimens at South Seymour Island and submitted these to the United States National Museum for classification.

*Galapagos distribution.*—This species was taken by the above mentioned expedition at Indefatigable, James and South Seymour Islands, Galapagos. The Harrison Williams Galapagos Expedition secured it at James, South Seymour, Indefatigable and Eden Islands, Galapagos, where Dr. Beebe records it as "common about salt ponds."

*General distribution.*—In addition to the above records this species was taken on the salt flats of Puerto Grande, Rio Zarumilla, Peru, by Dr. Robert E. Coker of the U. S. Bureau of Fisheries.

*Material examined.*—One female secured by the Arcturus Oceanographic Expedition at Cocos Island. The following specimen secured by the Harrison Williams Galapagos Expedition were also examined: two males from Eden Island (2042); two males (2624) from James Island; and two males (2139) from South Seymour Island, Galapagos.

*Color.*—A color plate of this species was made by Isabel Cooper. The carapace is light buff around the edges of the dorsal surface; the central portion

of the carapace is dark dull gray. The eye-stalks are light buff, the cornea deep gray, the chelipeds are orange cinnamon; the ambulatory legs are light buff.

*Habits.*—*Uca galapagensis* was found by William Beebe to be abundant on the salt marshes and tide flats of Galapagos. He also notes a less known haunt of these little crabs, in his "Galapagos—World's End" (p. 154):

"There were woods here, (James Island) real trees of moderate height, and we revelled in the luxury of shade and of walking almost free from broken lava. Mocking birds, fly-catchers and finches were numerous and even tamer than those we encountered elsewhere. They were curious too and followed us at arm's length, cocking their heads and inspecting us carefully. Now and then a scuttling sound as of some large animal in the carpet of dead leaves drew attention to a giant hermit crab hurrying away through the forest in the house that was his only by right of seizure. Fiddler crabs skittered about more quietly."

*Uca galapagensis* usually makes its home in burrows which it digs along the shore near the high water mark. It is gregarious, for although never more than a pair of crabs have been found occupying one hole, whole communities are found with the holes in close proximity to one another. These holes average three-quarters of an inch in diameter and extend downward for about eight to twelve inches, the upper corridor being nearly perpendicular, or a little oblique, and the lower chamber usually nearly horizontal. The work of digging these burrows is largely performed at night, or in the cool of early dawn when the tide is out. The huge chela of the male, and in the case of the females, either chela, form the shovel with which the sand is broken away. By cleverly coördinated manipulation the loosened sand is rolled into a pellet which is clasped by the three hinder anterior ambulatory legs, while the crab climbs out of its burrow by using its front anterior ambulatory leg and chela and its four posterior ambulatories. Upon attaining the entrance to the burrow the crab ludicrously scans the horizon with its long stalked eyes, and if satisfied that no enemy menaces, scuttles forward with its burden for at least a foot from the entrance, drops its burden, scurries back to the entrance, pauses, tip-toe, scans the horizon with its periscope eyes, and if all is well, loafs a bit at the doorway before returning to its den. The dexterity and rapidity with which these small crabs manipulate their huge claws in digging, and the engineering skill displayed in tunneling their "homes upon sand" is truly marvelous. One of the uses of their "voice," that is, the noise caused by the stridulating ridge of the giant chela, is to warn other members of the species that their particular burrow is inhabited, a warning that is usually respected.

The life cycle of this species has not yet been successfully worked out. No females carrying either eggs or young have been reported so far. However, the structure of the female abdominal appendages indicates that these crabs probably do carry the eggs at least during the pre-zoea stage.

*Technical description.*—Carapace 20 mm. wide at anterior margin, interorbital margin rounded, 4.5 mm. wide between eyestalks, 10 mm. wide at posterior margin; 13 mm. long in median dorsal line; strongly convex in all directions; surface finely punctate and sparsely setigerous; regions faintly indicated, except the H-depression of the urogastric region which is more definitely defined. The interorbital border at its widest point between the eyestalks is less than one-

fourth of the width of the anterior border of the carapace, and is clearly visible as a carinated edge in a normal dorsal view of the crab; the upper orbital border is sinuous and shows this carination continued, widening in the median area and vanishing near the anterolateral angle. The anterolateral angles are almost right-angled, but with the corner produced slightly forward; the anterior half of the lateral margins are out-curved, the posterior parts are moderately convergent, the posterior margin is relatively straight and is emphasized by a wide flat carina along its border. The inferior orbital margin is but little sinuous and forms a pronounced hiatus at the outer angle to accommodate the cornea; the entire margin is beaded, and setigerous both above and below this crenulation. The eyestalk consists of a short basal joint and a well-hinged, exceedingly flexible, long, cylindrical distal joint which reaches to the lateral margin; it is produced into narrow tongue-like projection on the dorsal surface which separates the margins of the cornea and terminates in a rounded process on the outer convex distal end; the cornea is elongate, cylindrical, decidedly more dilated than the stalk, very convex, situated obliquely—terminal, extending about two-fifths of the length of the distal joint of the eyestalk; the latter bears a dorsal longitudinal row of setae that function as "lashes."

The frontal and lateral walls of the carapace are high, strongly vaulted, the frontal region being tumid and coarsely tomentose; the upper margin of this tomentose area is distinctly channeled by a sulcus which extends from near the outer orbital angle inward to the efferent aperture near the outer distal angle of the external maxilliped.

The male abdominal belt is composed of seven segments, of which the first, second, third and fourth are of about equal width, while the fifth and sixth are microscopically narrower, and the seventh, which has its anterior margin broadly rounded, is slightly narrower than the sixth. The first and second segments are exceedingly short, their combined length being less than that of the third segment; the fourth segment is a trifle longer than the third segment; the fifth segment is a little longer than the fourth; the sixth segment is as long as the fifth; the seventh segment is only two-thirds as long as the sixth segment and is heavily fringed with setae around its anterior margin; it also bears a median transverse row of setae. The first pair of male appendages have an arched united base which arises from the first segment, and a pair of long slender curved processes that reach forward as far as midway the base of the chelipeds; these rods are three-sided, the wider side being that one appressed to the sternal plates, the angle formed by the union of the two narrower sides being the inner margin of the outer side of the appendage; the distal end of the appendage is rounded and curved, spoon-like, concave on its outer surface which is surrounded with close-set spinose setae, the inner surface is convex and bears a dense tuft of setae.

The female abdomen is also seven-segmented, but is very broadly oval, being nearly as wide as the sternal plates between the legs and reaching forward to the anterior margin of the first sternal plate. Its segments have the same length relationship as in the male; but the seventh segment in the female is only about half as wide as the sixth segment, whose antero-lateral angles are roundly produced. The lateral margins of all the segments are densely fringed

with long plumose setae. The second to third abdominal segments each bear paired appendages. Each appendage consists of a short peduncular joint, a long curved outer blade, whose proximal portion is directed diagonally inward toward the median line, the distal portion lying subparallel to this line. The appendages of the second segment have the outer blade only about half as long as the inner blade; the remaining appendages have the blades subequal. All the blades are heavily fringed with long silky setae.

The inner antennae are situated in a septum beneath the frontal margin; the basal angle is flat externally, dilated basally, narrowed distally, and bears two free, club-shaped articles which fold obliquely and fit into the septum; the proximal of these articles is slightly smaller than the distal and is dilated distally, filling the entire cavity when folded; the second article is also dilated distally and bears a rudimentary flagellum which consists of a short knob-like joint that is setigerous on its outer distal margin.

The external antennae have the basal joint much wider than long, bent transversely upon itself, set in the hiatus between the inner orbital angle and the inner antennal septum; the second joint, which is free, is much longer than wide, convex outwardly and closely appressed to the proximal end of the basal joint of the inner antennae and to the basal joint of the eyestalk; this second joint of the outer antennae bears a brush of fine long sensory setae on its anterior distal margin, and a palp arises from the posterior distal margin; this palp is composed of rather long cylindrical basal articles and about thirteen short, tapering rings and reaches about one-fifth of the length of the orbit.

The external maxillipeds are very large, being approximately one-third of the width of the carapace and nearly two-thirds as high as they are wide. The maxillipeds are separated from each other by a space equivalent to about two-thirds of the width of one maxilliped. They have the external surface setigerous and channeled, a longitudinal groove parallels the inner margin of the ischium and unites with one which curves around subparallel to the meral margins; all the margins of maxilliped are heavily fringed with long setae; the exognath is a slender, tapering rod which reaches half way the length of the merus and supports an inner whip-like palp that is about two-thirds as long as the rod, and is tipped with setae; the ischium of the endognath is rectangular and is about three-fifths as wide as long; the merus is about one-half as long as the ischium and has its outer lateral margin slightly produced near the base; the palp arises from the outer distal margin; the inner distal margin is rounded; the palp is three-jointed; the basal joint is about as long as the second and third, which are subequal, taken together, and is produced on its inferior lateral margin into a laminar projection which fits under the upper margin of the merus; the second and third joints, which are cylindrical, lie along the inner margin of the merus with their own margins adjacent but not touching; the palp is remarkably setigerous.

The chelipeds are strikingly unequal in the male, the propodus of the great chela in the specimen under discussion, being 28 mm. long and 10 mm. high while that of the small chela is 7 mm. long and 2.5 mm. high. The chelipeds of the female are approximately equal but are extremely small, those of a specimen 18 mm. anterior width, and 12 mm. long having a propodus scarcely 4 mm.

long and 2 mm. high. The great cheliped of the male has an unusually strong coxa, a small basis fused with the ischium which in turn is fused with the merus; the merus is three-sided, produced to a point on its distal surface and enlarged distally and is exactly one-half as long as the anterior width of the carapace; the joint between the merus and carpus is well-developed; the carpus is about three-fourths as long as the merus and slenderer, with its upper outer surface convex; the propodus when folded at rest, projects beyond the carapace for a distance equal to the entire length of the palm and the fingers extend across the front to the anterolateral angle of the opposite side. The palm is high, convex, outwardly carinated along its upper margin; the entire outer surface is granulate, that of the upper half, and especially of the carina, being more coarsely granular; a longitudinal row of setae parallel the upper marginal carina, running from the base of the propodus to near the base of the hinged finger; the propodal finger is less curved and somewhat shorter than the hinged finger, and tapers a little to a blunt apex; two rows of blunt crenulations form low tooth-like processes along the cutting edge of this finger. The hinged finger resembles the fixed finger in its general proportions and dentitions, but differs in having the distal end more tapering and decidedly curved. The fingers are widely gaping, meeting only at the tips. The small chela (male) resembles the large chela in the structure of its three basal segments but differs in having its merus very slender, elongate, not projecting outward beyond the carapace but directed upward, reaching as high as the anterolateral angle of the carapace, the carpus is convex outwardly and is about half as long as the merus; the propodus is rather flat with the palm as high as long and but little convex; the fingers are about three-fifths of the entire length of the propodus and are but little tapering, devoid of teeth on the cutting margins, but rounded spoon-shape distally, margined with a horny brown substance and fringed with tufts of setae. The female chelipeds resemble the small male cheliped in general structure but differ in having the palm thicker, more swollen, the fingers only about one-half of the entire propodal length; the propodal finger is carinated throughout the entire length of its outer surface by a line of denticles; the hinged finger is similarly carinated along the proximal two-thirds of its upper margin. The upper and outer surfaces of the propodus are also granular.

The male crab has the ambulatory legs distinctly longer than those of a female of equal size. In the male, the first ambulatory on the side with small chela and, a trifle less conspicuously, the first ambulatory behind the large chela, are distinctly directed obliquely forward from the meral joint instead of outwards, as are the three posterior pairs of legs. In the female this is even more conspicuous, as if the first ambulatories functioned in coöperation with, or as accessories to, the chelipeds. In the male the second pair of ambulatories are the longest, exceeding the first pair by the length of the dactyl and half the propodus; but being almost subequal in length to the third pair of legs; the fourth pair are the shortest reaching only one-third of the length of the propodus of the third pair. All of the ambulatories are similar in general structure, having the proximal three joints short, the merus the longest joint of the limb and also conspicuously widened and reticulated with transverse striations which are made up of minute granulations; the carpus and propodus taken together are



about as long as the merus, the carpus being only two-fifths of this; both joints are much narrower than the merus; the distal half of the carpus and the entire propodus is set with long spine-like hairs; the dactyl is very strong, slender, fluted, nearly as long as the propodus and set with several rows of short spine-like hairs.

There are accessory respiratory orifices between the basal joints of the chelipeds and first ambulatory legs; a second larger orifice between the bases of the second and third ambulatories.

*Uca helleri* Rathbun.

*Uca helleri* Rathbun, *Proc. Washington Acad. Sci.*, vol. 4, p. 277, pl. 12, figs. 3 and 4, 1902; *Bull.* 97, p. 415, pl. 151, 1917.

This species was apparently named for Edmund Heller, one of the naturalists of the Hopkins-Stanford Galapagos Expedition.

*Diagnostic characters.*—Carapace widest at anterolateral angles; orbits very oblique. Upper margin of propodus of male without a carina; oblique ridge continued to the upper margin.

*Type.*—The type, a male specimen; two additional males and a female were taken at Mangrove Point, Narborough Island, Galapagos Islands, March 1899, by the Hopkins-Stanford Galapagos Expedition and are deposited in the United States National Museum.

*Galapagos distribution.*—Mangrove Point, Narborough Island; Black Bight, Albemarle Island; Tower Island, *Arcturus* station 37.

*General distribution.*—Known only from the Galapagos Islands.

*Material examined.*—Three males and two females were taken at station 37, Tower Island, by the *Arcturus* Oceanographic Expedition.

*Technical description.*—Carapace 9 mm. long, .12 mm. greatest width between anterolateral angles; interorbital width (between the eyestalks) 1.6 mm. Carapace moderately convex in both directions minutely granulose and with scattered punctae; areolations very faint; frontal border narrow and obtusely rounded between the eyes, anterior margins sloping abruptly to the anterolateral angles; but little sinuous; the lower orbital margin is also visible in a dorsal view, being projected beyond the upper margin, and convex and finely denticulate. The anterolateral angles are prominent and practically right angled; the sides decidedly slope toward each other posteriorly. The male abdominal belt is seven-segmented, rather broad, with the distal segment rounded. The first pair of male appendages are long substantial rods, grooved on the outer side and bent inward just before the tips, which are tapering and channelled.

The female abdomen is seven-segmented, broadly oval and fringed with setae. The four pairs of biramous appendages are also fringed.

The inner antennae are situated in a septum beneath the frontal margin; the basal article is enlarged and flattened externally; it bears two club-shaped articles which fold obliquely and fit into the septum; the distal article supports the rudimentary flagellum.

The external antennae have the basal article much wider than long, bent slightly upon itself, set in the hiatus at the inner orbital angle; the next joint,

which is free, is about a third longer than wide, flattened slightly bent and fringed on its inner distal-lateral margin with three or four long, spinose setae; the third joint is slender, elongate, cylindrical and supports a tapering, six-jointed flagellum.

The external maxillipeds are rectangular and very close-fitting; their width is approximately equal to one-third of that of the carapace and their outer surfaces are setigerous and channelled; all the margins of the maxilliped are



Fig. 98. *Uca helleri*, male,  $\times 2.9$ .

fringed with setae—those of the inner edges being especially heavy. The exognath is very narrow and long; the ischium is rectangular, about three-fourths as wide as long; the merus is about half as long as the ischium and has its outer borders raised, convex, the palp is three-jointed, well-developed, setigerous.

The chelipeds are very strikingly unequal in the male, the propodus of the great chela of the specimen under discussion being 9 mm. long and 3 mm. high, while that of the small chela is only 3.5 mm. long and 1.1 mm. high. The chelipeds of the female are approximately equal but are exceedingly small and weak, those of a specimen 10 mm. wide having the propodus 3.7 mm. long; the fingers are spoon-shaped. The great chela of the male projects grotesquely beyond the body. The proximal three joints are small but very strong; the

merus is elongated, trigonal, with a transverse curved subdistal ridge on the inner face, and a corresponding ridge on the inner half of the upper surface; the carpus is small and is produced on distal point of the upper lateral margin into a rounded laminar process; the propodus is high and rather compressed with the outer side moderately convex, covered with granules which are larger on the upper surface and finer on the outer and lower parts, having a somewhat reticulated appearance. The oblique ridge of the inner surface is at an angle of approximately 45 degrees to the lower margin, turning at the middle of the palm at an obtuse angle and continuing in an irregular line to the upper margin. The surface between the ridges is nearly smooth. The fingers, which comprise slightly more than one-half of the propodal length, are subequal, long, slender and widely gaping. The cutting edges are finely denticulate and there is a larger tooth near the middle of the basal finger; also one at the basal third and occasionally another at the distal third of the hinged finger. In very young specimens these larger teeth are frequently absent. The fingers of the propodus of the small chela comprise about three-fifths of the propodal length and are gaping, meeting only at the broad corneous, spoon-shaped tips.

The four pairs of ambulatories are similar, all have the meral joint much elongated, in the anterior three pairs this joint is also dilated; the carpus and propodus taken together are about as long as the merus, but are much slenderer; the dactyli are approximately as long as the propodi and are very acuminate. All five pairs of legs are sparsely set with long, spinose hairs, which are more abundant on the distal joints.

Tribe: OXYSTOMATA

Family: CALAPPIDAE

Subfamily: CALAPPINAE

Genus *Calappa* Fabricius, 1798

*Calappa convexa* Saussure. (Purple Box Crab; Round Box Crab; West American Box Crab).

*Calappa convexa* Saussure, *Rev. et Mag. de Zool.*, ser. 2, vol. 4, p. 362, pl. 13, fig. 3, 1853; Rathbun, *Proc. U. S. Nat. Mus.*, vol. 38, p. 593, 1910; *Zoologica*, N. Y. Zool. Soc., vol. 5, no. 14, p. 158, 1924.

*Diagnostic characters*.—Carapace subcircular, very convex, with many rugosities on anterior region; chelipeds crested, hand with eight teeth on the upper margin. Color: lilac-lavender.

*Type*.—The type material came from Mazatlan, Mexico (Geneva Museum.)

*Galapagos distribution*.—Eden Island (Harrison Williams Galapagos Expedition), appears to be the first Galapagos record for this exquisite species.

*General distribution*.—Cape St. Lucas, Lower California, to Ecuador; Cocos Island; Galapagos Islands.

*Material examined*.—One large male specimen taken at Eden Island, Galapagos, by the Harrison Williams Galapagos Expedition; one small male from the stomach of a fish, Cocos Island, taken by the Arcturus Oceanographic Expedition.

*Color*.—A color plate of the large specimen secured at Eden Island was

made by the staff artist, Isabel Cooper. It shows the entire exposed dorsal surface of the crab to be an exquisite shade of lilac-lavender. The ambulatory legs are banded alternately with light rose and lavender on the three distal joints. This plate has been reproduced in Dr. Beebe's: "Galapagos-World's End," published by Putnam's, New York City.

*Technical description.*—The carapace is very convex, 64 mm. long, 87 mm. greatest width. The interorbital area is 8 mm. medium width, narrowing toward the frontal margin where two rounded horns are separated by a shallow u-shaped sulcus. Two lines indicate two closed sinuses on the superior orbital margin.

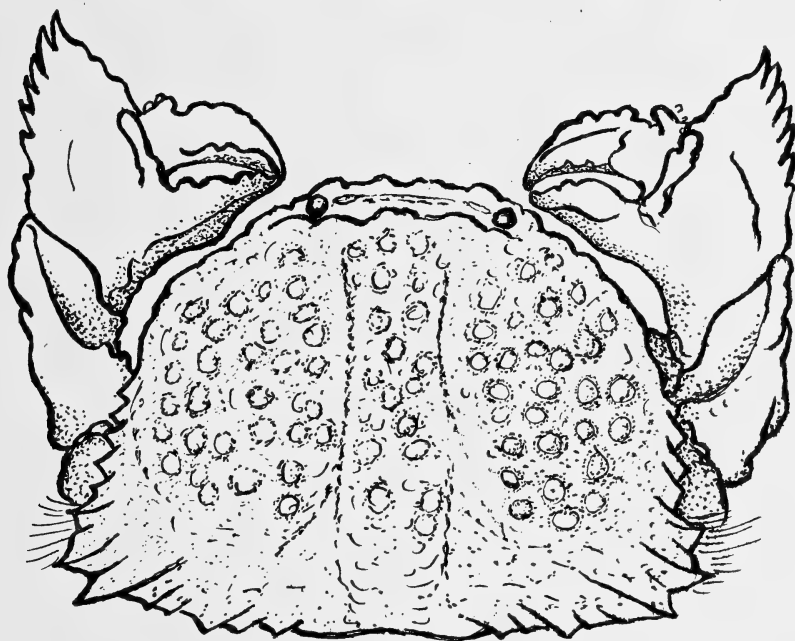


Fig. 99. *Calappa convexa*, natural size.

The anterolateral margins are rounded toward the front, from about midway to the posterior margin they are broken into 8 lateral teeth which increase in size posteriorly; the four most anterior teeth being small, obtuse; the first three are subequal, the fourth is a trifle wider; the fifth, sixth and seventh teeth are much larger and are produced to a triangulate point, each tooth successively increases in width and length posteriorly; the seventh being the greatest; the eighth is smaller than the seventh and has a prominent apex—its posterior margin is confluent with the posterior margin of the carapace which bears two small acute teeth. The carapace is covered with low rugose tubercles—those on the anterior two-thirds being much larger; those on the lateral area, smaller; on the posterior region the tubercles are replaced with linear rugosities. Bead-like carina midrib the seventh and eighth teeth and also the two pair of small

postlateral teeth. The regions of the carapace are definitely delineated. Two deep longitudinal channels groove the carapace, one on either side of the cardio-intestinal area.

The chelipeds are close-fitting, crested, the upper margin of the propodus being produced into a high crest serrated by eight triangular teeth.

The chelae are unequal, the larger claw is not any higher but the fingers are more strongly developed, the propodal finger is thick basally and has a large blunt tooth on its outer side—and another large high blunt tooth inner and sub-basal—this latter is followed by three successively smaller teeth along the cutting edge and the tip forms another acute tooth; the hinged finger has a large, curved, protuberant, rounded tooth basally and projecting on the outer side, which articulates between the two large teeth of the lower finger. The main part of the finger is very curved, and broken on the cutting edge to indicate three low molars. There is a large obtuse flattish process on the upper edge near the base of the hinged finger. The tip of the finger is sharp and fits upon the lower finger. The front face of the propodus bears several large tubercles and many small squamosities. There is a single prominent, acute tooth at the outer basal margin of the propodus; the outer posterior lateral margin of this tooth is somewhat rounded and finely crenulate and setigerous, its inner margin is only about half as long as the outer; the remaining lower edge of the propodus is emphasized by a beadlike carina which along the proximal two-thirds bears a fringe of setae. The merus surrounds and extends beyond the carpus and its outer margin is produced into four teeth, the most anterior tooth being the largest and pointed near the anterior part, its anterior lateral margins being short, the posterior margin about twice as long and truncated; the second tooth is three-fourths as wide as the first but is more triangulate, the third tooth is much smaller but is also triangulate; the fourth tooth has its postlateral margin evenly rounded. This winglike expansion of the merus coordinates with the produced wing of the carapace under which it fits, in forming a protective box-like cavity under which the four pairs of ambulatory legs may be concealed. The fingers of the small chela are slenderer and are without the large basal teeth. The propodal finger has seven subequal teeth in addition to the stronger pointed tip. The hinged finger is slender with a heavy fringe of setae on its upper margin and eight very small teeth along its cutting edge.

The four pairs of ambulatory legs are similar and successively decrease in size posteriorly. The dactyli are longer than the propodi and are fluted and pointed. The three distal joints are ringed alternately with light and dark color bands.

The male abdominal belt is five-segmented, the first segment being very short; the second segment longer and tuberculated; the third segment is three and one third times as long as the second and is composed of the third, fourth and fifth segments which are anchylosed; the fourth segment is not quite half as long as the preceding; the fifth segment is triangulate and is one and one-half times as long as the fourth. The external antennae are minute and are situated in the inferior orbital hiatus.

The external maxillipeds are very high reaching almost to the anterior margin of the carapace. They are set wide apart, being separated from each

other by a space equal to the width of the ischium. The exognath is very long and narrow and fringed on both edges with setae; the ischium is rectangular and finely denticulate and setigerous along the inner margin; the merus is about half as long as the ischium and is notched on the inner distal angle for the reception of the three jointed palp. The merus is covered with furry setae both on the edge and outer surface.

Family: LEUCOSIIDAE

Subfamily: LEUCOSIINAE

Genus *Leucosilia* Bell, 1855

*Leucosilia jurinei* Saussure.

*Leucosilia jurinei* Saussure, *Rev. et Mag. de Zool.*, no. 8, p. 12, pl. 1 b fig. 4, 1853; Bell, *Trans. Linn. Soc. London*, vol. 21, p. 294, pl. 32, fig. 1 1855; Rathbun, *Proc. U. S. Nat. Mus.*, vol. 38, p. 594, 1910.

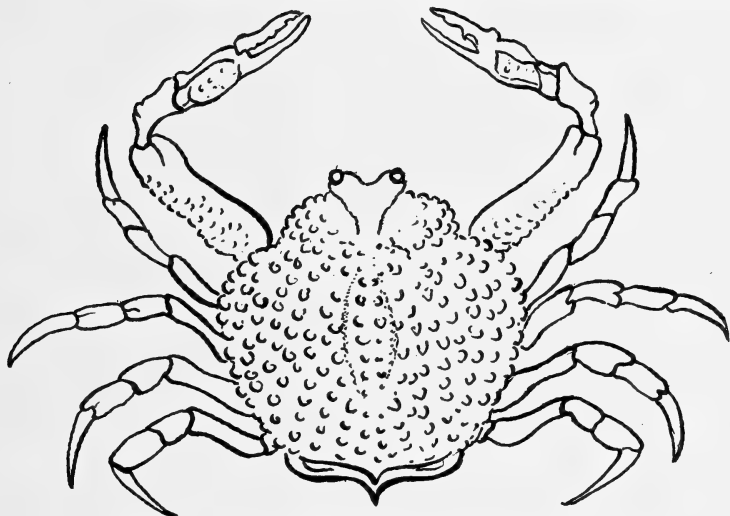


Fig. 100. *Leucosilia jurinei*,  $\times$  about 2 (After Bell).

*Name:* This beautiful species was named for M. Jurine.

*Diagnostic characters.*—Body globular in both sexes; a single small tubercle present on the posterior part of the carapace.

*Type.*—Saussure's type material came from Mazatlan, Mexico, and is believed to be deposited in the Geneva Museum.

*Galapagos distribution.*—Galapagos Islands.

*General distribution.*—Mazatlan, Mexico, to Peru and Galapagos Islands.

*Material examined.*—None.

*Technical description.*—The following is Mr. Bell's description of the type:

"Carapace orbicular, very convex, the sides rounded, the surface covered with large contiguous granulations, excepting on the frontal and part of the hepatic regions, which are smooth, there is a small elevation on each hepatic

region. The front with two small, triangular, divergent teeth, forming the hood-shaped roof of the antennary fossae, which are oblique and open. Orbit with three small fissures. There is a single obtuse tooth or tubercle on the intestinal region. External pedipalps with the outer branch very slightly curved, not dilated as in *Myra*, nor narrowed forwards as in *Persephona*, but with nearly parallel margins. Abdomen in the male very long, triangular, the penultimate segment with a strong, sharp tooth directed backwards; in the female broad, oval, very convex, with a broad central carina. The whole body above and below, with the exception before stated, covered with large granulations. Anterior legs much resembling those in *Persephona*, half as long again as the carapace, the arm granulated, the hand short and thick, the fingers slightly curved, armed with very small distinct tubercles, the points crossing a little when closed.

Genus *Persephona* Leach, 1817

*Persephona edwardsii* Bell.

*Persephona edwardsii* Bell; *Horae Carcinologicae*, vol. 21, p. 294, pl. 31, fig. 8, 1855; Rathbun, *Proc. U. S. Nat. Mus.*, vol. 38, p. 595, 1910.

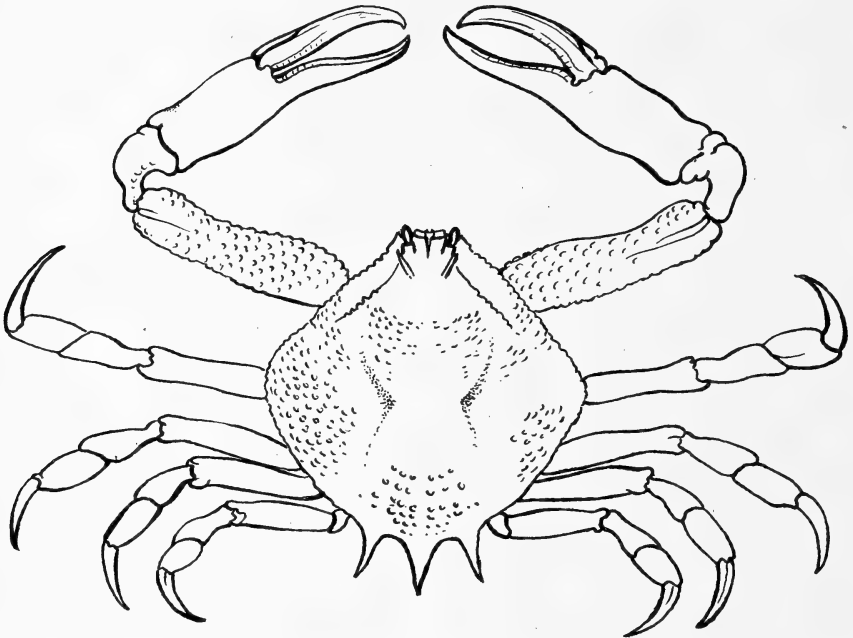


Fig. 101. *Persephona edwardsii*, about natural size (After Bell).

*Name:* This species was dedicated to Professor Milne Edwards.

*Diagnostic characters.*—Carapace suborbicular, somewhat produced and narrowed anteriorly, pterygostomian angle obsolete; marked by only a slight elevation.

*Type*.—This species was founded on two specimens collected in the Galapagos Islands, depth 6 fathoms, by D. Cuming. I have not been able to ascertain the present repository of these specimens.

*Galapagos distribution*.—Galapagos Islands, dredged in coral sand at six fathoms.

*General distribution*.—Panama and Galapagos Islands.

*Material examined*.—None..

*Technical description*.—The following is Mr. Bell's description of the type:

"Carapace nearly orbicular, somewhat produced and narrowed anteriorly, minutely punctate, covered, excepting at the anterior portion, with very small distinct granules, of which a distinct line borders the latero-anterior portion; the anterior margin waved, the pterygostomian angle obsolete, marked only by a slight elevation. Front broad, slightly emarginate; lateral and posterior margin much rounded, the spines placed in nearly a right-angled triangle, nearly equal, recurved at the apex. Anterior legs with the arm everywhere tuberculated, the wrist slightly granulated on the inner side, the hand minutely punctate. External pedipalps as in *P. orbicularis*. Abdomen (female) slightly granulated at the posterior and lateral portions.

Colour pale buff.

Length of carapace 1.3 in."

#### Subtribe: DROMIACEA

#### Family: DROMIIDAE

#### Genus *Dromidia* Stimpson

#### *Dromidia larraburei* Rathbun.

*Dromidia sarraburei* Rathbun, Proc. U. S. Nat. Mus. vol. 38, p. 553, vol. 48, fig. 4, 1910 (error for *larraburei*, Rathbun).

*Dromidia larraburei* Schmitt, Univ. of California, Pub. Zool. vol. 23, p. 183, pl. 33, fig. 1, 1921.—Rathbun, Bull., Amer. Mus. Nat. Hist., vol. 48, p. 619, pl. 33, figs. 1-4, 1923.

*Diagnostic characters*.—A *Dromidia* with the carapace high, subglobular; anterolateral margins are directed obliquely inward toward the buccal cavity and are furnished with four small teeth.

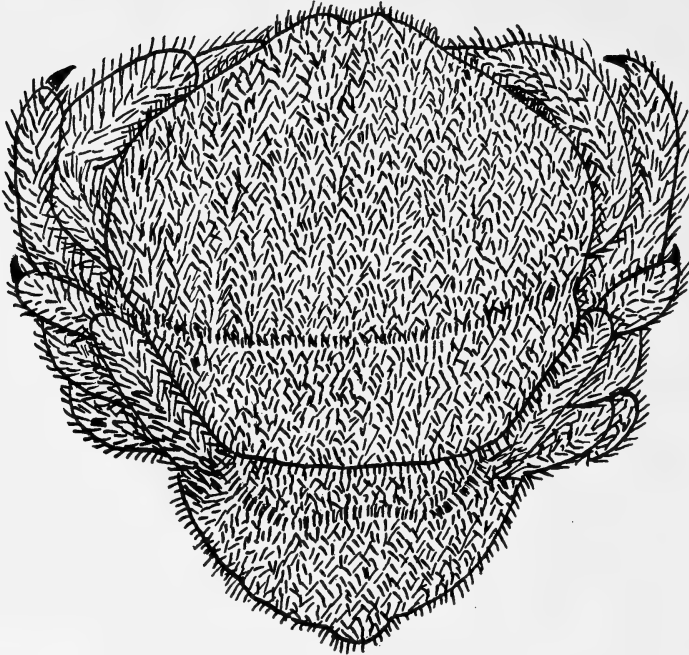
*Type*.—The type was taken in the Bay of Sechura, west of Mataballa, Peru, in about 5 fms., by Señor Don Carlos Larrabure y Correa, and is deposited in the collections of the United States National Museum.

*Galapagos distribution*.—A broken female, also a last-stage megalops were taken at station 54, off Hood Island, in 15 feet of water, by William Beebe. This appears to be the first authentic record of this species from the Galapagos Archipelago, although Schmitt lists Galapagos in his discussion of the species he fails to state where his Galapagos specimens are deposited or by what expedition they were secured.

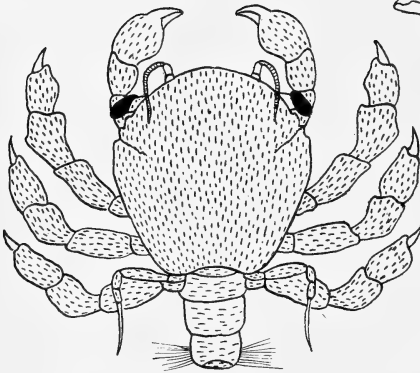
*General distribution*.—Sechura Bay, Peru, 5 fms.; Monterey Bay and Long Beach, California; Magdalena Bay, Lower California; Galapagos Islands.

*Material examined*.—One adult and one megalops from station 54, off Hood Island, Galapagos, secured by William Beebe, while diving in 15 feet of water.





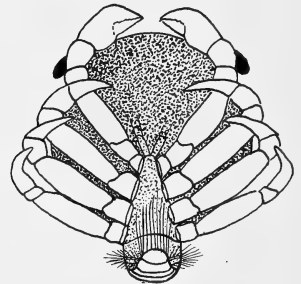
102A



102B



102D



102C

Fig. 102A. *Dromidia larraburei* Rathbun, adult  $\times 2$ ; B. megalops, dorsal view  $\times 4$ ; cheliped; C. ventral view of same megalops; D. cheliped of megalops.

*Technical description.*—Carapace with the dorsal surface convex, approximately as long as the maximum width which is across the mesogastric region, while posterior border which is three-fourths as wide as the mesogastric region represents the minimum width. The interorbital region is very narrow depressed, concave, produced to a short, conical, median rostral tooth, which is in line with the antennary peduncles; just behind the median tooth the frontal border is produced into a pair of prominent submedian teeth which are situated one at each inner superior orbital angle. The superior orbital margin is sinuate, being produced to a small denticle approximately midway its length; the inferior orbital margin is much shorter than the superior border, and terminates inwardly in a prominent denticle. The anterolateral margins are directed obliquely inward toward the buccal cavity and are furnished with four small teeth which are nearly concealed under the dense fur-like pilosity which covers the entire carapace and legs except the tips of the fingers of the chelipeds and dactyli. The hepatic region is slightly concave. There is a decided oblique furrow extending inward from the base of the most posterior lateral tooth across to the branchial region vanishing in confluence with the grooves which define the cardiac region. The urogastric line is the most prominent, terminating in a pit at each end, from which another groove curves forward on the mesogastric region bifurcating, one branch running forward toward the orbital border, while the other, more definite branch runs outward to the base of the third anterolateral tooth. The sidewalls of the carapace are high, vaulted, flattened, fitting closely against the merus of the chelipeds. The male abdominal belt is triangulate, composed of seven segments.

The chelipeds are subequal, large, stout, with the meral joint trigonal, fitted closely against the carapace, armed with a row of five (or six), subequally spaced, low-rounded tubercles forming a longitudinal line along the anterior lateral margin of the merus; there is a transverse, subdistal constriction on the outer face of the merus; the carpus is quite as long as the hand of the cheliped and is rounded on the outer surface; there is a decided tooth on the outer lateral margin of the carpus; another median carpal tooth at the distal margin and a third slightly smaller subdistal tooth at the termination of the inner lateral margin; the hand is stout, convex on its upper and outer surfaces, three-fourths as high as long and armed with a longitudinal series of three low, rounded, subequally spaced tubercles along the upper margin of the inner face; the propodal finger is short, stout, triangular, armed with four subequal triangulate teeth along the margin and with the tip broad, rounded, and channelled; the hinged finger fits closely upon the propodal, but has its upper surface curved; it is armed with three teeth along the cutting edge, in addition to the apical tooth.

The first and second pairs of ambulatory legs are similar, having the merus, carpus and propodus stout, the dactyli less so with a curvate horny tip, also a row of horny spines on the inferior lateral margin. The third and fourth pairs of ambulatory legs are subdorsal, smaller, prehensile, bent sharply at the meral-carpal joint and terminating in strong hook-like dactyli. There is a short sharp spine on the distal end of the propodus with which the tip of the dactyl interfits. The fourth pair of legs is much longer than the third

pair, and are closely appressed to the carapace, recurved, the bent meral carpal joint reaching half way the length of the carapace.

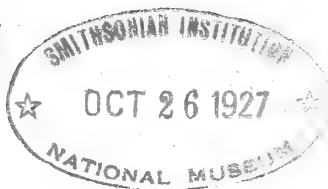
*Megalops*.—The single megalops taken (figs. 102B and C), shows the characters of the species in the shape and ornamentation of its carapace and chelipeds.

# ZOOLOGICA

## SCIENTIFIC CONTRIBUTIONS OF THE NEW YORK ZOOLOGICAL SOCIETY

DEPARTMENT OF TROPICAL RESEARCH  
ARCTURUS OCEANOGRAPHIC EXPEDITION

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VOLUME VIII. NUMBER 5

Department of Tropical Research Contribution Number 250

### CONTRIBUTIONS TO THE EMBRYOLOGY OF THE AMERICAN EEL (*ANGUILLA ROSTRATA* LESUEUR)

BY MARIE POLAND FISH

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*Assistant, United States Bureau of Fisheries*

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# CONTRIBUTIONS TO THE EMBRYOLOGY OF THE AMERICAN EEL (*ANGUILLA ROSTRATA* LESUEUR)

BY MARIE POLAND FISH<sup>1</sup>

Assistant, N. Y. Zoological Society Department of Tropical Research  
Assistant, United States Bureau of Fisheries

(Figs. 103-116 incl.)\*

## OUTLINE

- I. THE ARCTURUS SPECIMENS.
  - COLLECTION AND DESCRIPTION OF EGGS.
  - EMBRYOLOGY AND LARVAL DEVELOPMENT.
- II. COMPARISON WITH PREVIOUSLY DESCRIBED MURAENOID EGGS.
  - FIVE UNIDENTIFIED SPECIES OF RAFFAELE.
  - UNFERTILIZED CONGER EGGS (*Leptocephalus conger*).
  - AN UNIDENTIFIED EGG BELIEVED BY SOME INVESTIGATORS TO BE THE EUROPEAN EEL (*Anguilla vulgaris*).
  - FERTILIZED EGG, EMBRYOLOGY, AND LARVAL DEVELOPMENT OF CONGER
    - Description of Egg.
    - Development of Yolk.
    - Jaws.
    - Color.
    - Finfold.
  - NINE UNIDENTIFIED SPECIES OF BOEKE.
    - Muraena helena*.
    - Nettastoma melanurum*.
    - Ophichthys hispanus* and *Ophichthys serpens*.
- III. COMPARISON WITH PREVIOUSLY DESCRIBED LEPTOCEPHALI AND ADULT EELS.
  - DISTRIBUTION.
  - PRELARVA OF EUROPEAN EEL.
  - PRELARVA OF AMERICAN EEL.
  - MYOMERE COUNT.
- IV. IDENTIFICATION AS AMERICAN EEL.
  - CHARACTER OF THE EGGS.
  - LOCATION OF THE COLLECTING GROUND.
  - COMPARISON OF THIS PRELARVA WITH THE SMALLEST KNOWN EUROPEAN EEL.
  - COMPARISON OF THIS PRELARVA WITH THE SMALLEST KNOWN AMERICAN EEL.
  - MYOMERE COUNT.

<sup>1</sup>Contribution, New York Zoological Society Department of Tropical Research, No. 250.

\* Figs. 103-109, 114 and 116 drawn by Dr. Charles J. Fish; Figs. 110-113 after Eigenmann; Fig. 115 after Schmidt.

## V. HISTORY OF THE EEL QUESTION.

THEORIES CONCERNING REPRODUCTIVE METHODS OF THE EEL AND  
SEXUAL ORGANS.

CAUSES OF ERRONEOUS BELIEFS.

LOCATION OF THE SPAWNING GROUND.

## I. THE ARCTURUS SPECIMENS

## COLLECTION AND DESCRIPTION OF EGGS

The one-hundredth station made by the "Arcturus Oceanographical Expedition," on July 15, 16, and 17, 1925, proved to be an extremely interesting collecting-ground, not only because certain specimens were taken here which were found nowhere else, but

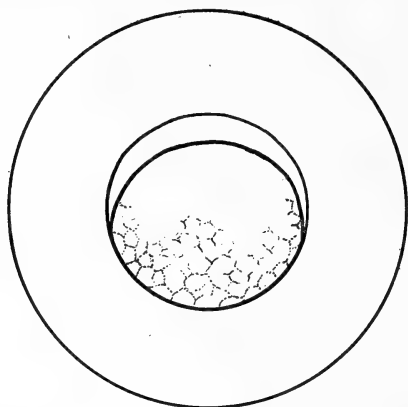


Fig. 103. Egg of American eel, July 16, 1925, probably very soon after fertilization.

because the immediate locality had been worked upon in former years by the "Challenger," "Plankton," and "Bache Expeditions," and later by the Danish Commission for the Exploration of the Sea under the direction of Johannes Schmidt. This position (lat. 32° 02' N. long. 65° 00' W. at noon on July 16) is approximately ten miles southwest of Bermuda on the Challenger Bank, a shoal about five miles in diameter and only twenty-four fathoms at its shallowest depth. Intensive collecting carried on in the deeper regions on the edge of the Bank revealed a rich marine life.

On July 16 four eggs were found in a Petersen young fish trawl from five hundred fathoms, the lowest of a line of nets towed at various levels. These tiny specimens closely resembled the few

known eggs of eels and eel-like fishes. They were highly transparent, colorless except for a slight yellowish tinge of the yolk, and measured 3.3 millimeters in outside diameter (Fig. 103). No oil globules were present. They were further characterized by a very wide perivitelline space, the diameter of the yolk measuring 1.7 millimeters. A very early stage in development had been reached, the germinal

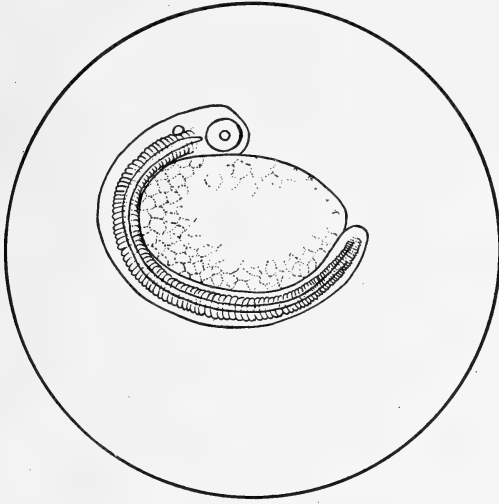


Fig. 104. Egg of American eel about 88 hours after stage shown in Fig. 103.

disc defined but without evidence of cleavage. The eggs did not float at the surface but remained near the bottom of the fingerbowl until hatched. Because of the small number of eggs and the difficulty of microscopic work on shipboard, the notes were unfortunately rather fragmentary.

#### EMBRYOLOGY AND LARVAL DEVELOPMENT

At 9 A.M. on July 17 the cleavage stages were past and the embryo barely defined, reaching about one-quarter around the yolk.

Three days later (9 A.M., July 20) the embryo had reached two-thirds around the yolk, and yolk and embryo maintained a position uppermost in the egg. The embryo was elongated, colorless; muscle segments, eyes, auditory vesicles, notachord, and yolk blastopore well differentiated. The yolk was vesicular, as is the case in certain



clupeiods, appearing under the microscope as though it were broken up into a mass of cells.

On the eighth day (8.30 A.M., July 23) the embryo in one egg was nearly around the yolk, and very active—the whole embryo pulsating rapidly. The vertebrae and pectoral fins were prominent. Black pigmentation had begun in the rim and iris of the eye, and the pupil was gray. The embryo in another egg was further advanced, had lost the very elongated shape and become more flattened laterally and proportionately much deeper. There was more black pigment in the iris than in the preceding stage. A third egg had the black pigment confined to a tiny bar on the upper margin of the eye with two dots below. The heart was very active. The pronounced beak-like projection of the upper jaw, and the vesicular yolk with a narrow stalk extending backward nearly to the region of the vent were typical of a muraenoid embryo. This embryo was more than two-thirds around the egg, situated high up.

The fourth egg hatched between midnight and 8 A.M. on July 23, approximately one week after fertilization. During this incubation period the temperature of the water in which the eggs were kept had varied from 27.7° centigrade when cleavage began, to 23.9° centigrade at hatching. From the egg emerged a leptocephalus 9 millimeters long, very transparent, and colorless except for ocular pigment. In life there appeared to be a very few black chromatophores on the caudal portion of the embryonic fin, but as this region was somewhat mutilated after death, their presence cannot definitely be established. The larva was very slow in its movements the first day, floating motionless near the surface and swimming only when disturbed.

Fig. 105 shows the leptocephalus when first observed. There is no suggestion of an oil globule and the yolk is completely absorbed. The embryonic fin envelops the body without trace of finray formation. The hypural elements are not evident. The pectorals are prominent and the teeth well developed, as Fig. 106 shows, three pairs resembling fangs in the upper jaw, and four pairs in the lower.

On July 24 the three remaining eggs were dead, but the larva seemed to be thriving well. It swam rapidly and almost constantly with characteristic eel-like motion. The length at twenty-four hours was 10 millimeters. Fig. 107, made one day after Fig. 4, shows the rapid development of the teeth.

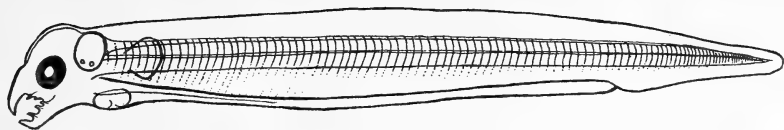


Fig. 105. Prelarva of American eel soon after hatching, 9 mm. long. (8 A.M., July 23)

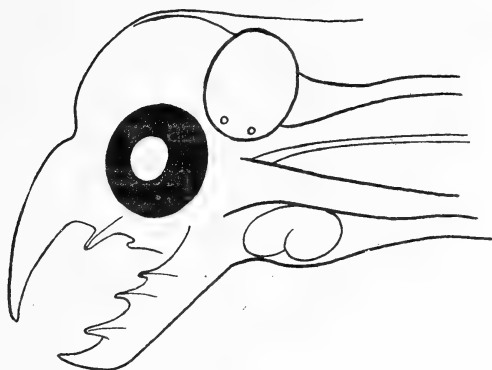


Fig. 106. Head of prelarva shown in Fig. 105.

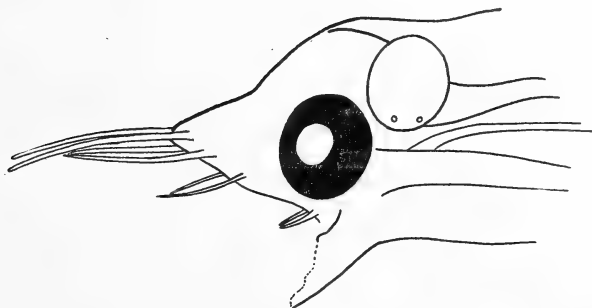


Fig. 107. Head of same prelarva shown in Fig. 106 one day later, demonstrating the extremely rapid development of prelarval teeth.

On the morning of July 25 the larva had died and was considerably shriveled. It had been impossible before, because of the activity of the single larva, to count the segments, and the determination in the injured condition was difficult. There were, however, between 105 and 110 muscle segments, this small difference in recorded number made necessary by the almost indistinguishable caudal myomeres. An embryo freed from the egg was found to have at least 105 and not more than 109 segments, about 64 of them preanal and 41 postanal.

## II. COMPARISON WITH PREVIOUSLY DESCRIBED MURAENOID EGGS

### FIVE UNIDENTIFIED SPECIES OF RAFFAELE

Before attempting to identify the present specimens, it will be necessary to examine carefully the existing knowledge concerning young eels. In 1888 at the Naples Zoological Laboratory, F. Raffaele hatched out the pelagic eggs of five species of eels, collected from August to November, and found certain characters common to them all:

- 1) very large size distinguishing them at first glance from the other eggs taken,
- 2) large perivitelline space,
- 3) delicate egg membrane without pore canals, ordinarily with iridescent reflections,
- 4) structure of yolk, being entirely vesicular.

The differences between the various species, as shown on the chart p. 295, were in size, in the presence and number of oil globules, in pigmentation, and especially in the number of muscle segments in the embryos which developed.

### UNFERTILIZED CONGER EGGS (*Leptocephalus conger*)

In 1891 J. T. Cunningham described the unfertilized eggs of a conger eel, which he obtained at the Southport Aquarium, England, on July 24, 1889. The eggs were squeezed from the female and one measured, after the formation of the perivitelline space, 1.6 millimeters. The formation of the perivitelline, which occurred within an hour after extrusion, indicated to Cunningham that the eggs were nearly ripe but not that they had necessarily acquired the char-

Raffaele's Species	Character of the Egg			Character of the Larva
	Diameter	Oil Globules	Description	
No. 6	2.0-2.5 mm.	1 (for the most part)—5, of 0.3-0.35 mm.	Perivitelline space very broad; yolk vesicular, diameter 1.2-1.3 mm. On third day of incubation swelling occurs on oesophagus (oesophageal pouch).	Abdominal segments 72 (73?). Larva very elongate, compressed. Head relatively small; intestine not open posteriorly but ending about halfway to the edge of the ventral finfold; fourth ventricle of heart enormous; on second or third day of life outside the egg the mouth opens and it develops long and pointed teeth in the two jaws; at same time there appear 6 large black pigment spots along trunk ventrally.
No. 7	More than 3.0 mm.	6-12, which, during development of embryo, occupy posterior part of yolk.	(Note: Schmidt, 1913, believes quite certainly that this is <i>O. hispanus</i> , same as Boeke's No. 3.)	Abdominal segments 59 (60?). Differs from preceding principally in its shorter length, and the absence of pigment spots.
No. 8	2.0-2.5 mm.	More than 30, usually yellowish, scattered over the whole distal surface of yolk.	Similar to No. 6 but perivitelline space a little narrower.	Abdominal segments 72 (73?).
No. 9	2.0 mm.	1, club-shaped and placed anteriorly during development of embryo.	Vitellus attached to membrane by filaments.	Abdominal segments 66 (67?). Similar to No. 6 but very much narrower.
No. 10	2.7 mm.	None		Abdominal segments 44 (45?). Similar to No. 6.

The present species may be compared with those of Raffaele:

Present species	3.3 mm.	None .	Perivitelline space broader than others, diameter 1.7 mm.; yolk vesicular.	Abdominal segments 64; elongate, compressed, intestine ending at margin of ventral finfold; fourth ventricle enlarged; mouth open and teeth well developed at hatching; no ventral line of pigment spots but few near extremity of caudal finfold, and eye pigmented in embryo.
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acteristics that would show in the perfectly ripe egg. They were chalk-white, opaque, with no oil globules, and sank to the bottom in seawater of density 1.027.

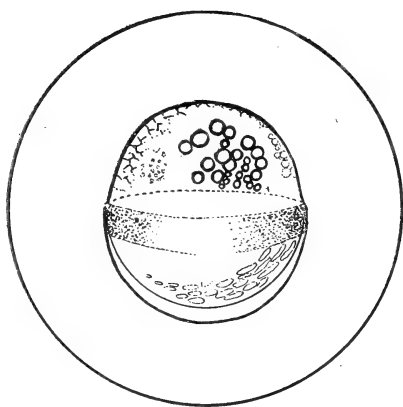


Fig. 108. Egg of Species No. 7 of Raffaele. Drawn from Raffaele.

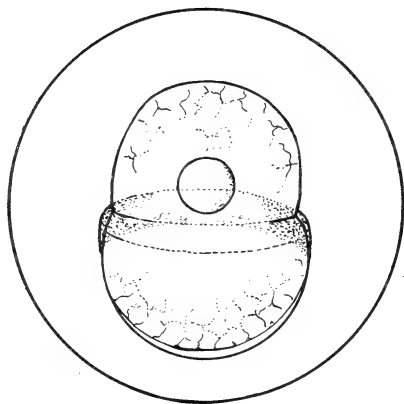


Fig. 109. Egg of Species No. 6 of Raffaele. Drawn from Raffaele.

AN UNIDENTIFIED EGG BELIEVED BY SOME INVESTIGATORS TO BE  
THE EUROPEAN EEL (*Anguilla vulgaris*)

Five years after the unfertilized conger egg had been reported, 1896, Grassi and Calandruccio identified as the common European eel one of the eggs of Raffaele's list. "From the study of Raffaele on pelagic eggs, I have come to the conclusion that the eggs of his undetermined species No. 10, having a diameter of 2.7 millimeters and differing from all the others in the absence of oil globules, must belong to the *Anguilla vulgaris*, because from them Dr. Raffaele obtained prae-larvae which had only forty-four abdominal myomeres." Concerning their seasonal distribution, Grassi states: "Eggs which according to every probability belong to the common eel, are found in the sea from the month of August to that of January inclusive."

This identification has been questioned by E. W. L. Holt (1907) on the ground that it is at variance with our knowledge of the unripe ovarian eggs of the European eel, but he gives no description of the egg as he believes it to be. The prelarva 6 millimeters long figured by Schmidt (1924) has a large oil globule which would seem to evidence the same occurrence in the egg. On the other hand Syrski's (1873) observations support the belief in an absence of oil globules in an immature condition. "The ovaries of young eels of the length of about 500 millimeters contained invariably little fat and the eggs were without globules." The larger of these ovarian eggs measured about 0.2 to 0.25 millimeters in diameter.

The same difference of opinion prevails concerning the immature egg of the American species. Bigelow (1924) states: "Eel eggs have not been seen, but certainly they are provided with an oil globule, as this is present in unripe ovarian eggs and in the vestiges of the yolk sac of the youngest embryos." However Eigenmann (1901), in discussing eel eggs which might occur in American waters, takes the opposite stand: "The common eel egg has been identified as one without an oil globule." He is doubtless confusing the American and European species, basing his statement on Grassi and Calandruccio's disputed claim to the identification of the European eel egg.

Some "silver eels," or eels which have begun their seaward migration and are clothed in spawning attire, I placed alive in a salt water aquarium at the U. S. Bureau of Fisheries at Woods Hole, Mass., in November, 1925. On February 5, 1926, one specimen, 70

centimeters long, was found in a dying condition. The ovaries were examined and found to contain unripe eggs of various sizes up to 0.25 millimeters. Another eel, 66 centimeters long, which died on April 8, contained eggs up to 0.32 millimeters. A third specimen, on May 5, had eggs up to 0.32 millimeters, also.

The last silver eel was examined on December 22, 1926. During thirteen months of confinement this specimen had not eaten, although it had been tempted with squid and other foods, nor had it changed, apparently, in size. The ova within measured up to 0.45 millimeters, the largest, to my knowledge, which have been recorded. The experiment is being repeated this year, and it is hoped that these eels may be kept alive for even longer periods.

#### FERTILIZED EGG, EMBRYOLOGY, AND LARVAL DEVELOPMENT OF THE CONGER

The first American contribution to the embryology of muraenoids was made in 1901 when Carl H. Eigenmann succeeded in hatching out some eggs which he provisionally identified as those of the conger eel (*Leptocephalus conger*). Eigenmann's drawings and careful descriptions have been of great value in comparison with the present species. The eggs were taken by the U. S. B. F. Schooner *Grampus* on the tile-fish grounds, about thirty miles south of South Shoal, off Nantucket, Mass., on July 31, 1900. Hitherto eel eggs had been found only in the Mediterranean, and even there they had been observed within a limited area.

(1) Description Of Egg.—The eggs described by Eigenmann were very similar to Raffaele's No. 6.

Species	Diameter of Egg	Character of of Vitellus	Oil Globules	Abdominal Segments
No. 6 (Raffaele)	2.0–2.5 mm.	1.2–1.5 mm. diameter	1–3 of 0.3–0.35 mm.	72 (73?)
Conger eel (Eigenmann)	2.4–2.75 mm. (Six pre-served eggs measuring 3 mm. may be identified with these)	1.75–2.0 mm. diameter	1–6 light yellows of variable size	65–71

The conger eggs, as shown above, measured 2.4 to 2.75 millimeters from membrane to membrane; the vitellus measured 1.75 to

2.0 millimeters and was of the vesicular texture typical of all eel eggs. There were from one to six oil globules of variable size. When several were present, one was always much larger than the others.

(2) Development Of Yolk.—The yolk of the conger eggs had certain characteristics in common with the present egg. Its bulk was in the usual position with a narrow stalk extending backward below the intestine nearly to the region of the vent. The anterior portion was broadly rounded when first observed by Eigenmann (Fig. 110). As development went on, however, and the yolk diminished

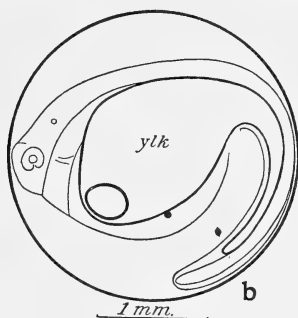


Fig. 110. Egg of conger eel when first observed, showing characteristic shape of yolk.

in size, the most anterior part became more and more constricted until it formed a mere protuberance enclosing the oil sphere. In the present embryos, which contained no oil spheres, the anterior contour apparently remained rounded. By further constriction the oil sphere of the conger egg became elongate, and the posterior stalk of the yolk beneath the alimentary canal somewhat larger as its anterior part diminished. In succeeding stages the slender yolk sac acted as a pericardial chamber. The yolk sac was observed disappearing at wide intervals along its entire length by constrictions which deepened gradually until a series of minute globules more or less widely separated from each other were all that remained.

Some of the eggs were found hatching on August 3, the third day after the stage observed in Fig. 110. The jaws of many of these were gaping, a condition not found in those which took several days longer to hatch. Eigenmann believed the gaping jaws to be an abnormality which might be due to an unusually early hatching.

(3) Jaws.—The development of the jaws is a character which differs considerably in the conger and the eel described in the present



paper. Fig. 111 shows a conger larva soon after hatching. The mouth is not distinguishable. Fig. 112 shows a larva two days later with the jaws in a stage of development which was passed in the present eel several days before hatching. Fig. 113 is the conger larva about three days after hatching. The mouth is in about the same condition as the present one when first observed, (see Fig. 105), less than twelve hours after hatching, or hardly more developed than that of the embryo several days before.

Raffaele first observed the mouth opening on the second day after hatching. This was followed by a rapid development of the teeth. There were three pairs in the upper jaw, a character in common with the present *leptocephalus*. Eigenmann's conger developed four pairs in the upper jaw, graded from front to back, the anterior ones comparatively enormous fangs. In the lower jaw of his specimens were four pairs of more uniform size, the second one larger than the others. A condition of which he questions the normality is the appearance of five pairs of teeth in the lower jaw of the oldest individual. The present species had four pairs in the lower jaw.

(4) *Color*.—In the conger color appeared first in the tail region, and the following six spots were evident above the alimentary canal and along the margin of the myotomes of the tail on the second day of larval life: (1) about middle of yolk, (2) halfway between this and end of yolk, (3) at end of yolk, (4) in front of anus, (5) some distance behind anus, (6) about the tip of tail. These spots were placed in approximately the same location as the enlargements formed by the constriction of the yolk sac. More pigment spots appeared between those already formed, but the number was constant in larvae of the same age, although the relative and actual size varied greatly in individuals. A few pigment cells appeared in the upper jaw, and a few scattered cells near the tip of the lower jaw developed later into a well-marked spot.

The presence of pigment in the conger differs decidedly from that of the present eel. Although the latter was not kept alive until the time when chromatophores would have appeared in the conger, the eye had pigment in the embryo before hatching. It had appeared first as a tiny bar on the upper margin of the eyeball with two dots below. A slightly later stage had the whole outer margin of black with large blotches over the iris, and the pupil gray. At hatching the iris was solid black. The formation of pigment in the

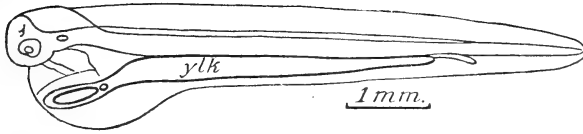


Fig. 111. Prelarva of conger eel soon after hatching.

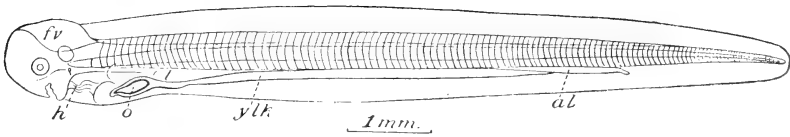


Fig. 112. Prelarva of conger eel two days later than stage shown in Fig. 111.

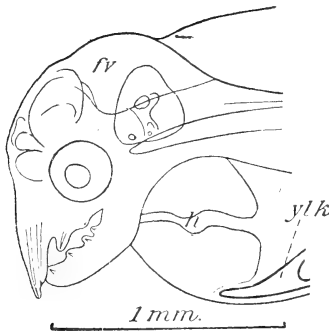


Fig. 113. Head of conger eel prelarva about  $3\frac{1}{2}$  days old.

eye of the conger occurred with its first appearance on the body, about three days after hatching.

(5) Finfold.—The finfold of the conger is continuous from the nape to the yolk sac. In the species described in this paper, how-

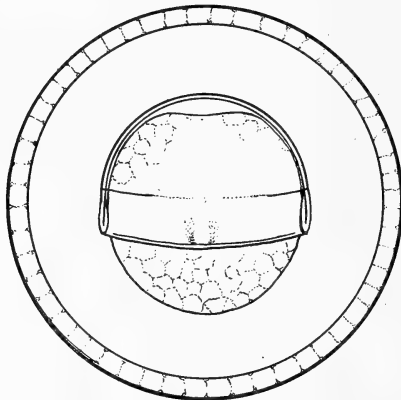


Fig. 114. Egg of *Muraena* No. 7 of Boeke, showing the type of muraenoid egg which has a delicate inner membrane attached by filaments to the outer capsule. Drawn from Boeke.

ever, the finfold apparently extends from the nape only to the anus, which is located back three-fourths of the distance between tip of jaws and end of tail. If the finfold does continue forward below the intestine, it is so narrow that it was indistinguishable in the living specimen. The intestine of the conger, although equal in length at this stage, lies just below the muscle segments, and even in the latest stages observed by Eigenmann (about eleven days after hatching) the intestine was remote from the margin of the ventral finfold, which continued forward to the remaining fragments of the yolk.

#### NINE UNIDENTIFIED SPECIES OF BOEKE.

In 1903 J. Boeke described the eggs of nine species of eels, taken during the summer months of 1900 and 1901 near the Zoological Station at Naples. Five of these species had previously been recorded by Raffaele (1888). The characteristics of the various eggs are indicated below.

Species	Character of the Egg			Character of the Larva
	Diameter	Oil Globules	Description	
<i>Muraena</i> No. 1 (No. 6 Raf.)	1.8-2 mm.	1-5 lying close together.	Perivitelline space very broad; diameter yolk 1.1-1.3 mm. Mouth and anus closed in egg.	Abdominal segments 67-72. When yolk completely absorbed, length about 10-15 mm., sharp teeth, and 6 pigment spots on trunk.
<i>Muraena</i> No. 2.	3.3 mm.	7-12, somewhat smaller than those of Mur. No. 1 and not so thickly grouped.	Diameter yolk 1.7 mm. Mouth and anus open in egg.	Abdominal segments 75-77. Teeth and 6 pigment spots formed before hatching. Length at hatching about 7-8 mm.; at absorption yolk about 15 mm.
<i>Muraena</i> No. 3 (No. 7 Raf.)	3.3 mm.	As Mur. No. 2.	As Mur. No. 2.	As Mur. No. 2 but with abdominal segments 59 (60?).
<i>Muraena</i> No. 4 (No. 8 Raf.)	2.2 mm.	30 or more.	Diameter yolk 1.4 mm. Mouth and anus closed at hatching.	Abdominal segments 65-67 at absorption of yolk.
<i>Muraena</i> No. 5	2.9 mm.	Many, small globules concentrated into opaque, whitish mass about size of a single globule in Mur. No. 1.	Diameter yolk 1.5 mm. Mouth open and teeth formed in egg.	Abdominal segments 58-60.
<i>Muraena</i> No. 6 (No. 9 Raf.)	Somewhat smaller than Mur. No. 1.	1, long drawn-out shape like tear.	Double membrane to egg capsule, inner delicate and attached by filaments to outer.	Abdominal segments at hatching 59. Abdominal segments at absorption of yolk 63. (Raf. gives 66 (67?)).
<i>Muraena</i> No. 7.	2.6 mm.	None.	Diameter yolk 1.5 mm. Capsule as in Mur. No. 6.	Abdominal segments 54 (55). Colorless except for few pigment cells at anus and tail end.
<i>Muraena</i> No. 8 (No. 10 Raf.)	2.6 mm.	None.	As Mur. No. 7.	As Mur. No. 7 but with abdominal segments 44 (45?).
<i>Muraena</i> No. 9	2 mm.	10-16 quite closely congregated.	Diameter yolk 1.1 mm. Double capsule as in Mur. No. 6.	Prelarva died a short time after hatching and no segment count obtained.

## MURAENA CONGER.

Schmidt (1913) described the eggs of another conger, *Muraena helena*, which were widely distributed in the upper layers of the Mediterranean over and near the coastal banks during July, August, and September. The eggs measured 4-4.5 millimeters and were without oil globules. They were further characterized by a thick

capsule, large perivitelline space, and the embryos had from 144 to 148 muscle segments.

#### NETTASTOMA MELANURUM.

Large numbers of the eggs of *Nettastoma melanurum* Raf. were taken by Schmidt in the Balearic and Tyrrhenian Seas. They occurred in the surface as well as in the deeper layers during January and February, being the only muraenoid eggs collected on the winter Mediterranean cruises of the *Thor*. They measured 2 to 3 millimeters in diameter and contained no oil globules. The embryos were without teeth or pigment and had from 55 to 60 preanal myomeres. Older leptocephali (12-82 millimeters) referred to this species had 63-66 preanal and c. 140-143 postanal myomeres.

#### OPHICHTHYS HISPANUS AND OPHICHTHYS SERPENS.

Schmidt has identified Raffaele's "Species No. 7" and Boeke's "Muraena No. 3" with *Ophichthys hispanus*, and the latter's "Muraena No. 2" with *Ophichthys serpens*. In both species the mouth is open and most of the characteristic preanal pigment, "gut patches," are developed before the embryo is hatched. The yolk sac is stalked, as in other muraenoids, and the "borsa stomacale" or local swellings of the digestive tract are very large.

### III. COMPARISON WITH PREVIOUSLY DESCRIBED LEPTOCEPHALI AND ADULT EELS

#### DISTRIBUTION

Were the number of Atlantic fishes that pass through a leptocephalic stage small, our task of determining the present specimen would be lightened. The records of previous expeditions, however, show many such larvae, at least forty-five species having been completely (with vertebral count) described, as well as fifteen or more species of adults of which the leptocephalid young have not yet been distinguished. That some of these species remain in the larval form for long periods, as the three-year leptocephalus of the European eel (*Anguilla vulgaris*), and the fact that during this stage the animal is carried about passively by currents, leads us to expect certain ones in far separated localities. For this reason, again, we are unable to narrow our list of possibilities to a very few.

Almost nothing is known concerning the places of spawning of muraenoids, so that it is not possible to interpret our eggs on the

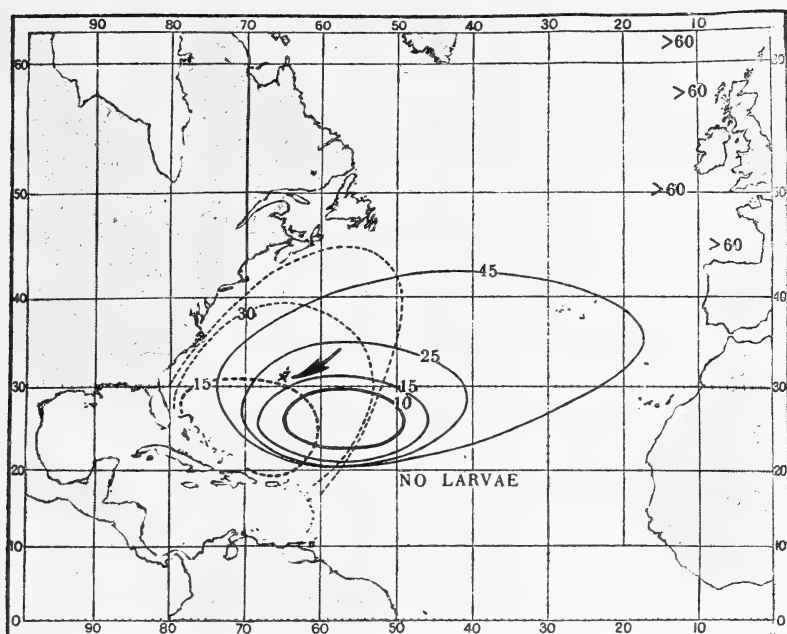


Fig. 115. European Eel (*Anguilla vulgaris*) and American Eel (*Anguilla rostrata*)

Breeding areas and distribution of larvae shown by curves; dotted for American, continuous for the European species. The heavily-drawn innermost curves embrace the breeding areas of the two species. The curves show limits of occurrence; i. e. specimens less than 25 mm. in length have only been found inside the 25 mm. curve, etc. The cross (x) marks the spot where the present American eel eggs were taken.

basis of such knowledge alone. We do know, however, that the station from which they came was very close to, if not well within, the limits of the breeding grounds of both the American eel, *Anguilla rostrata*, and the European eel, *Anguilla vulgaris*. The cross (x) on Fig. 115 marks the location of these eggs, lat. 32° 02' N., long. 65° 00' W. It is just outside the curve which designates the breeding area of the American eel and within which all larvae were smaller than 15 millimeters, and is within the 25 millimeter length curve of the European eel. Schmidt (1924) notes the limits of larval *Anguilla* distribution as follows:

American eel (*Anguilla rostrata*) larvae

Northernmost find: Lat. 42° 19' N., long. 50° 22' W.

Southernmost find: Lat. 17° 55' N., long. 64° 48' W.

Westernmost find: Long. 82° 59' W., lat. 20° 08' N.

Easternmost find: Long. 50° 22' W., lat. 42° 19' N.

*European eel (Anguilla vulgaris) larvae*

Northernmost find: Lat. 61° 21' N., long. 10° 59' W.

Southernmost find: Lat. 20° 14' N., long. 57° 03' W.

Westernmost find: Long. 73° 43' W., lat. 35° 42' N.

Easternmost find: Long. 15° 35' W., lat. 38° 07' N.

## PRELARVA OF EUROPEAN EEL.

The illustration by Schmidt of an European eel six millimeters long shows decided differences from the present prelarva, although the general proportions of the body and the teeth are strikingly



Fig. 116. Smallest known prelarva of European eel, 6 mm. in length. Drawn from Schmidt.

similar. The eye of the European eel is pigmentless, whereas the eye of this eel is black; a large oil globule serves to differentiate it further. The presence of pigment on the caudal portion of the embryonic fin is probably identical in the two species (see p. 292).

## PRELARVA OF AMERICAN EEL

The smallest American eel prelarva previously recorded was pictured by Schmidt (1916). It measured 10½ millimeters after preservation and was obviously in a later stage of development than my specimen. The dental formula  $\frac{1+3}{1+3}$  was identical in the

two prelarvae, but the teeth of Schmidt's specimen were more even, stronger and less tapering, like those of older leptocephali. The depth of the body of the latter was slightly greater, a change which is known to occur as development progresses. Pigmentation, as in the present specimen, was restricted to the eye and a few black stellate chromatophores on the embryonic fin near the tip of the tail (not on the tail itself). The number of myomeres was the same.

## MYOMERE COUNT

A character which remains constant throughout the life history of the eel—through the prelarval, leptocephalid, hemilarval, elver,

and adult stages—is the number of muscle segments or vertebrae. This has been the principle accepted for distinguishing species. Einar Lea (1910) examined the records and descriptions of all species of young and adult eels and found those which give the vertebral count limited to twelve species with larval stages known, twenty-three species with larval stages unknown, and forty-four unidentified larvae. Weber (1913) added descriptions of seven more species taken by the Siboga Expedition, but none of these were Atlantic forms. The chart following is taken from Lea's work on the *Michael sars* muraenoid larvae (1910), with the addition of species subsequently recorded, and includes all those eels for which I have found the myomere count.

Name of Species	Number of Segments	Name of Species	Number of Segments
SPECIES, THE LARVAL STAGES OF WHICH ARE KNOWN		larva:	199-206
<i>Cyema atrum</i> Gunther	73	<i>Ophichthys serpens</i> (Linnaeus)	208
larva: <i>L. cyematis atri</i>	75-77	larva:	209-212
<i>Anguilla rostrata</i> LeSueur	103-113	<i>Saurenhelys cancrivora</i> Ptrs.	200
larva: <i>L. grassii</i>	105-109	larva: <i>L. oxyrynchus</i>	240-249
<i>Anguilla mauritiana</i> Bennett		SPECIES, THE LARVAL STAGES OF WHICH ARE NOT YET IDENTIFIED	
larva:	105-108	<i>Muraenesox coniceps</i> Jord. & Gilbert	111
<i>Gastrostomus bairdii</i> Gill & Ryder	110	<i>Anguilla japonica</i> (Schleg.)	112-119
larva: <i>L. gastrostomi bairdii</i>	108	<i>Echidua catenata</i> Bleek	116
<i>Anguilla vulgaris</i> Turt.	111-119	<i>Gymnothorax meleagris</i> Shaw	120
larva: <i>L. brevirostris</i>	111-119	<i>Gymnothorax nebulosus</i> Bl.	122
<i>Congromuraena balearica</i> de la Roche	about 130	<i>Echidua cocosa</i> Garm.	...
larva: <i>L. taenia, inornatus, diaphonus, eckmani</i>	123-137	<i>Echidua nebulosa</i> Garm.	...
<i>Chlopsis bicolor</i> Raf.	133	<i>Echidua scabra</i> Garm.	123
larva:	131-136	<i>Moringua raitaborua</i> Ham.	126
<i>Congromuraena mystax</i> de la Roche	about 138	<i>Gymnothorax undulatus</i> Lacep.	126
larva: <i>L. haeckeli, yarrelli, bibroni, gegenbauri, kollikeri, stenops</i> (in part)	132-147	<i>Histiobranchus infernalis</i> Gill	130
<i>Muraena helena</i> Lin.	139-143	<i>Ilyophis brunneus</i> Gilb.	127-132
larva:	140-143	<i>Ophichthys ocellatus</i> Les.	132
<i>Synaphobranchi pinnatus</i> Gronov	146-151	<i>Echidua zebra</i> Bleek	132
larva: <i>L. synaphobranchi pinnati</i>	144-157	<i>Gymnothorax unicolor</i> de la Roche	134-135
<i>Conger vulgaris</i> Cuv.	146-164	<i>Ophichthys gomesi</i> Casteln.	136-140
larva: <i>L. stenops</i> (in part), <i>morrisii, punctatus</i>	142-159	<i>Gymnothorax ocellatus</i> Agas.	.....
<i>Ophichthys hispanus</i> (Bellotti)	154-159	<i>Gymnothorax moringa</i> Cuv.	141
larva:	154-159	<i>Conger marginatus</i> Val.	142
<i>Ophichthys imberbis</i> (de la Roche)	156-159	<i>Serrivomer sector</i> Garm.	144
larva:	156-159	<i>Muraenesox cinereus</i> Forsk.	145
<i>Nettastoma melanurum</i> Raffaele		<i>Ophichthys frontalis</i> Garm.	149
		<i>Xenomystax rictus</i> Garm.	154
		<i>Gordiichthys irretitus</i> Jord. & Davis	157
		Garman	173
		Jord. & Davis	225



Name of Species	Number of Segments	Name of Species	Number of Segments
LARVAL FORMS, NOT IDENTIFIED		<i>Leptocephalus longidens</i> Garm.	140
<i>Leptocephalus taenia</i> Lesson	106-115	" <i>strommani</i> E. and K.	141
" <i>similis</i> Lea	110	" <i>thorianus</i> Schmidt	142
" <i>holti</i> Schm.	112	" <i>morrisii</i> E. and K.	142
" <i>peterseni</i> Weber	112	" <i>oculus</i> Peters	c.142
" <i>indicus</i> Weber	115	" <i>hjorti</i> Weber	144
" <i>diptychus</i> E. and K.	122	" <i>mucronatus</i> E. and K.	144-147
" <i>euryurus</i> Lea	116-117	" <i>megacara</i> Lea	149-150
" <i>obtusius</i> Garm.	119	" <i>falcidens</i> Garm.	about 153
" <i>dentex</i> Cantor	about 120	" <i>ingolfianus</i> Schm.	153-155
" <i>rex</i> E. and K.	119-123	" <i>discus</i> E. and K.	155-159
" <i>dentatus</i> Garm.	121	" <i>lanceolatus</i> Stromm	158-163
" <i>amphioxus</i> E. and K.	122	" <i>enchodon</i> Lea	158
" <i>spinocadur</i> Lea	125	" <i>humilis</i> E. and K.	157-162
" <i>michael-sarsi</i> Lea	127	" <i>lanceolatoides</i>	
" <i>anguilloides</i> Schmidt	132	Schmidt	163
" <i>caudomaculatus</i> E.		" <i>lychnus</i> Garm.	165
and K.	133	" <i>gilberti</i> E. and K.	180
" <i>mysticus</i> Lea	about 127	" <i>hjorti</i> Blegvad	182
" <i>cingulus</i> Garm.	131-133	" <i>rostratus</i> Schmidt	188-191
" <i>dolichorhynchus</i> Lea	128-136	" <i>urosema</i> Lea	190
" <i>latus</i> E. and K.	133	" <i>telescopicus</i> Schmidt	200-210
" <i>histiobranchi infer-</i>		" <i>canarius</i> Lea	200-220
nalis or <i>Ilyophidius</i>		" <i>stylurus</i> Lea	218-229
<i>brunnei</i> Lea	133-134	" <i>latissimus</i> Schmidt	240
" <i>splendens</i> Lea	135	" <i>andreae</i> Schmidt	about 250
" <i>acus</i> Garm.	135	" <i>sicarius</i> Garm.	" 250
" <i>schmidtii</i> Weber	135	" <i>mirabilis</i> Brauer	293
" <i>gilli</i> E. and K.	137	" <i>polymerus</i> Lea	about 443
" <i>cinctus</i> Garm.	138		

Such differences as the number of finrays, which have been used alone by certain describers to differentiate species, are often useful to supplement the myomere count, for we find individuals of the same species varying somewhat as well as more than one species with the same number of muscle segments.

#### IV. IDENTIFICATION AS AMERICAN EEL

By comparing our specimen with the above list we see that the known *leptocephalus* of *Anguilla rostrata*, the American eel, which has been described as *Leptocephalus grassii* Eigenmann and Kennedy, is nearest, the number of muscle segments coinciding exactly. No other species of which the larval stage is known comes within twenty of this count except the European eel, *A. mauritiana*, and *Gastrostomus bairdii*. The hatched specimen as well as the embryos

removed from the eggs have less than 111 segments, and the other differences in pigmentation and the absence of an oil globule, make it reasonably safe for us to eliminate the European species. *A. mauritiana* is barred by its distribution, being a member of the Indo-Pacific fauna but not of the Atlantic.

The leptocephalus of *Gastrostomus bairdii* has a like count, but although no young of this species has been taken smaller than 33 millimeters, Einar Lea believes that the smaller stages would be of the type of leptocephali described as *Leptocephalus latus* by Schmidt (1909), and later as *Leptocephalus latissimus*. It has a deep, leaf-shaped body, totally unlike the form of the present leptocephalus.

*Muraenesox coniceps*, an adult form described by Jordan and Davis (1888) has 111 segments but is found only in the Pacific Ocean. A closely related Atlantic species, *M. savanna*, ranges from Cuba to Rio Janiero, but the myomere count is not recorded. The young of the two species have not been seen, and the slightly greater number of segments is our only negative evidence.

The distribution of *Anguilla japonica*, which is found only in the northwestern Pacific, would preclude this species, as would the larger segment count.

*Leptocephalus similis* Einar Lea has 110 segments, but the short high head and rounded tail are quite unlike this specimen. The same differences are evident between it and *Leptocephalus euryurus* Einar Lea, a species taken near the coast of Morocco, having 116 segments.

Weber gives the number of segments of two specimens of *Leptocephalus taenia* Lesson taken by the Siboga Expedition as 106 and 115. This species, however, has the intestine terminating almost at the posterior end of the body, different dentition, and other characteristics distinguishing it definitely from ours.

A specimen of *Leptocephalus peterseni* Weber has 112 muscle segments, but here again the form of the body is entirely different, being deeper and less tapering posteriorly, and the shape of the head and the teeth are peculiar.

*Leptocephalus indicus* Weber, taken in the Sulu-See, has 115 myomeres, but the species would hardly have so wide a distribution. Only one specimen, 115 millimeters long, is known.

By the above process of elimination it seems evident that of

those species for which the number of muscle segments is known, only the American eel can qualify for consideration. Had we descriptions of the young of all living eels, we might with certainty attribute our leptocephalus to this particular species. Every expedition at sea, however, captures more new species, and so it is only provisionally that we call these eggs and the young developing from them *Anguilla rostrata*. The evidence for this identification may be summed up as follows:

### 1. CHARACTER OF THE EGGS

The eggs were definitely those of an eel or eel-like fish, evidenced by their large size, large perivitelline space, vesicular-stalked yolk, and slightly iridescent cell-membrane, which was fine in texture and showed no pore canals, as well as by the leptocephalid character of the larvae hatching from them. They were different from any muraenoid eggs previously observed.

### 2. LOCATION OF THE COLLECTING GROUND

The eggs were found within the same general area designated by Schmidt to encompass the breeding grounds of the American and European eels, and without doubt had been floating only a very short time. The latter fact is indicated by the early stage of development reached at the time of capture (germinal disc defined but without evidence of cleavage) and the rapidity with which incubation proceeded. The first egg hatched in seven days. It is impossible to say exactly how far above the bottom they were floating, but the trawl was towed at 500 fathoms below the surface in water of between 500 and 2116 fathoms depth.

The depths at which eels spawn and their eggs develop have been speculated upon by various investigators, but no actual data have been secured. Raffaele believed spawning to take place at great depths and the eggs to remain there unless some unusual condition caused a few to mount higher in the sea. Eigenmann attacked the latter conclusion on the ground that Grassi had found eggs of eels at the surface, and all species were typical of pelagic eggs, being lighter than water, having oil spheres and other characteristics of eggs which normally live in the surface layers. He remarks: " 'If fertilization takes place at great depths' it must be 'only exceptionally, for unknown reasons,' that they remain at the

great depths. The fact that Raffaele never secured eggs younger than when the gastrula was well formed would favor the supposition that they were fertilized at a great depth and rose slowly in the water."

In the absence of closing net hauls it is impossible to state at just what level our eggs were taken. At the time of their collection four surface nets were towing, meter nets at 300 and 400 fathoms, and a meter net and a Petersen young fish trawl at 500 fathoms. The fact that no eggs were taken in the meter net at the same depth would seem to mean that the eggs were not abundant, or that they drifted by higher up after the other nets had been hauled. The Petersen trawl was at the end of the cable and in its hauling towed through the levels where the other nets had been. The meshes of the various plankton nets on the line were sufficiently small to retain eggs of this size had they entered, but were it not for a red shrimp and a few transparent sagittae which helped to imprison them, the eggs would no doubt have passed through the half-inch meshes of the trawl. The shrimp is typical of the Intermediate or Black Zone, so-called, about 800 to 1500 meters, and the Sagittae of the Transition Zone which is, in this region, about 400 to 800 meters.

If we were able to conclude, from the fact that the eggs were collected only by the deepest net, that they were taken while towing at 500 fathoms and not during its passage from this depth to the surface, then the early stage of development attained would favor the theory of fertilization at great depths.

### 3. COMPARISON OF THIS PRELARVA WITH THE SMALLEST KNOWN EUROPEAN EEL

Since the two species *Anguilla rostrata* and *Anguilla vulgaris* are so closely allied that distinction is based mostly upon a difference of only a few muscle segments, it is logical to suppose that the earliest larval stages will show like similarity. The present prelarva strikingly resembles the European eel prelarva in the general proportions of the body and the teeth, but the pigmented eye and the absence of an oil globule, as well as the difference in myomere count, show them to be separate species.

#### 4. COMPARISON OF THIS PRELARVA WITH THE SMALLEST KNOWN AMERICAN EEL

Schmidt (1916) figures a prelarva of this species  $10\frac{1}{2}$  millimeters long, which, although in a later stage of development, has many characters in common with my specimen. The dental formula  $\frac{1+3}{1+3}$  is identical in the two prelarvae, but the teeth of Schmidt's specimen were more even, stronger, and less tapering, like those of older leptocephali. The depth of the body of the latter was slightly greater, a change which is known to occur as development progresses. Pigmentation in both prelarvae was restricted to the eye and a few black chromatophores on the embryonic fin near the tip of the tail. The number of myotomes (104–110 in Schmidt's eel, 105–109 in this) was the same.

#### 5. MYOMERE COUNT

A character which remains constant throughout all stages of development is the number of muscle segments and vertebrae. According to the principle adopted by most investigators interested in the eel question, "A species is regarded as new when it differs from all species formerly described where the number of muscle-segments is stated" (Lea). This leptocephalus has the same number of muscle segments as the American eel, and no other larva known from Atlantic waters nor adult species of an eel (except *G. bairdii*) has this count. Of those species which have a number of muscles segments within twenty of the present specimen, there are other specific differences which allow their elimination (i.e. *Anguilla vulgaris*, *Anguilla mauritiana*, *Anguilla japonica*, *Gastrostomus bairdii*, *Muraenesox coniceps*, *Leptocephalus similis*, *Leptocephalus taenia*, *Leptocephalus peterseni*, and *Leptocephalus indicus*).

Our specimens, with approximately 105 to 109 segments, may be compared with seven young eels identified as *Leptocephalus grassii*, taken at Woods Hole, Mass., during the summer of 1900, in which the count was 106, 107, 107, 108, 109, 110, and 107, as recorded by Eigenmann and Kennedy (1901), and with the count of ten elvers 50 to 60 millimeters in length taken at random from many collected on May 20, 1926, in the U. S. Fisheries Boat Basin, Woods Hole—104, 106, 106, 106, 107, 105, 107, 111, 108, and 108.

## V. HISTORY OF THE EEL QUESTION

THEORIES CONCERNING THE REPRODUCTIVE METHODS OF THE EEL  
AND THE SEXUAL ORGANS

The difficulty in determining our scant number of eggs, four in all with only one living long enough to hatch, can be better understood when we consider the enigma which the eel question has always presented. It was not until 1874 that a male specimen was distinguished and a controversy which had lasted for almost twenty-three centuries ended. Many great scientists of all times have speculated upon the mysterious reproductive methods of the eel. In 1880 Jacoby published an interesting history of man's attempt to solve this question, which beliefs we may profitably review here, for the floundering of these writers concerning eel reproduction, in strong contrast to their other attainments, in many cases, surely demonstrates the difficulty of the problem. When the early Greeks failed to find spawn and milt within the eel, they jokingly named Jupiter as the father of these fishes, to whom they were in the habit of ascribing all children of doubtful parentage.

The first record of a serious attempt at explanation was made by Aristotle (384-322 B.C.), some three hundred and fifty years before Christ. This great master of thought contended that eels as well as smaller animals were born from the earthworms *Lumbricus terrestris*, which, in turn, were produced spontaneously from mud and moist soil. Aristotle came to this conclusion even though he had previously recognized, "by the crackling of the eggs when placed over fire," the ovaries of the "grongo" (*Leptocephalus conger*).

In the first century after Christ the Roman scholar Pliny the Elder, (Gaius Plinius Secundus, 23-79 A.D., author of "Naturalis historia," a work in its present form consisting of thirty-seven books), ventured the belief that young eels were produced from fragments rubbed off by the adults against the rocks, a different version of the abiogenetic myth.

Athenaeus and Oppian held the same opinion, varying it sometimes to the procreation from a slimy mass produced by the rubbing together of their bodies.

Albertus Magnus, writing in 1254, repeated again the hypothesis that the rubbing of eels against the rocks produced young, but added that, he had been told, eels could also be born alive.

Three hundred years later, 1555, Rondelet brought forward two entirely different ideas. He maintained that young were produced from putrified matter as well as by eggs resulting from the copulation of male and female eels. In 1558 the writings of Konrad von Gesner (1516–1565) echo these two methods of reproduction.

The next suggestion, and one which was held by many succeeding scientists, was that of Marcello Malpighi (1628–1694), great student of physiology and anatomy. An expert microscopist, also, Malpighi was the first to apply the microscope to the study of plant and animal structure. Such discoveries are attributed to Malpighi as the first actual observation of capillary circulation, the structure of secreting glands, and of the lower stratum of the epidermis, the vasicular coils of the cortex of the kidneys, the follicular bodies in the spleen, and the first knowledge of the finer anatomy of the brain,—and yet this keen observer failed to identify correctly the ovaries of eels and eel-like fishes, as the “grongo” (*Leptocephalus conger*) and the “muraena” (*Muraena helena*), believing these organs to be deposits of fat and giving them the name of “striae adiposae.”

Other microscopists failed to recognize as such the eel ovaries. Francisco Redi in 1684 identified unmistakably those of the “muraena” but not those of the eel. A noteworthy achievement of this scientist, however, was the refutation of the theory that eels are born from decaying matter. The “young eels” which others had found within the adults, and on which evidence partly was based the belief in viviparity, Redi showed were intestinal worms and firmly contended that eels reproduced by the spawning of eggs. Redi and Cristian Franz Paullini, living also in the seventeenth century, were the first to bring forward the belief that the reproduction was not unlike that of other fishes, although they did not themselves observe the eggs and semen within the eels.

A contemporary of Redi was the famous Dutch microscopist Anthony von Leeuwenhoek (1632–1723), whose researches gave us our first description of blood corpuscles, detailed accounts of the structure of muscle tissue, the crystalline lens, and the teeth. In examining the urinary bladder of an eel, Leeuwenhoek found a number of minute parasitic worms. The bladder, he maintained, was the uterus and the worms within were young eels. A common belief at this time was that eels were produced from dew.

Georg Elsner reported having seen an eel with uterus full of young.

In 1710 Professor Antonio Vallisneri of the University of Padua pictured the real ovaries, but following the theories of those before him, believed them to be fatty organs, "vasi adiposi." In one specimen he found a swim-bladder deformed by disease, and not recognizing it as a pathological condition, announced that he had at last discovered the "true ovary" of the eel. The small round granules which he mistook for eggs were later shown by Mundini to be swelled glands.

Vallisneri's assertion caused grave doubts and heated discussions among the Academy of Bologna scientists, and so possessed with a desire to discover the ovaries were they that, Jacoby relates, Professor Pietro Molinelli promised several fishermen of Comacchio a large reward for a pregnant eel. In 1752 a live eel was brought to him with stomach much distended, and found to be full of eggs. The crafty fisherman, with an eye to the reward no doubt, had opened up the specimen and crammed the stomach with the eggs of another fish.

Carl von Linné (1707-1778), known to biology as the founder of the binary system of nomenclature and author of more than one hundred and eighty published works, adhered to the doctrine that eels were viviparous.

It was not until 1777 that the ovary of the eel was recognized, the honor of the discovery belonging to Carlo Mundini, professor of anatomy at the University of Bologna. An eel resembling that described by Vallisneri seventy years before was caught near Comacchio, sent to the Academy of Bologna, and subsequently given to Professor Cajetan Monti. Too ill at the time to examine the specimen himself, Professor Monti, in consultation with some of his scientific associates, resolved to turn the investigation over to Mundini. The latter's description and excellent drawings, however, although given on May 19, 1777, to the Academy of Bologna, were not published until 1783. Three years previous, in 1780, Otto Friedrich Müller published the finding of eggs within the eel, but certain inaccuracies in his statement tend to give Mundini precedence.

The notable achievement of Mundini was not to stand undisputed and a few years after it was attacked by Lazzaro Spallanzani (1729-1799), who professed to have examined four hundred and ninety-seven eels without being able to confirm the former's dis-



covery. He maintained that the ovaries shown by Mundini were merely unusually fat folds of the diaphragm. It has been pointed out, however, that Spallanzani's attack smacks more of personal animosity than of just criticism based on conflicting results.

Martin Heinrich Rathke, writing between 1824 and 1850, again gave a detailed account of the eel ovary, quite accurately describing the egg within. He added little, however, to the work of Mundini. His article, published in "*Müller's Archiv*" in 1850 on a pregnant eel examined by him, permanently settled the dispute.

Certain mistakes in Rathke's work were corrected in 1874 by Syrski, Director of the Museum of Natural Sciences at Trieste and professor in the University of Lemberg. This scientist has the honor of first recognizing the spermatic organs of the eel. The search for the male, which, thus, did not end until ninety-six years after the finding of the ovaries, was also marked by erroneous beliefs.

In 1872 Reinhold Hornbaum-Hornschuch had stated the discovery of a male individual, indicated by the possession of round bodies enclosing small granules, in the fringed bodies of a number of eels, where eggs appear in the female.

So difficult of solution was the question that leading zoologists of the day were forced to conclude that "eels may reproduce by means of parthenogenesis, or by being of different sex, or also by being hermaphrodites."

Two years before the work of Syrski, Professor Giovanni Battista Ercolani at Liepzig asserted in memoir-form, with illustrations, that he had found both the true testicle and a rudimentary testicle within the eel. Syrski, however, showed the "true testicle" to be a sac on the left side formed exceptionally by the peritoneum, and corresponding in position to a mass of fat attached to the swim-bladder between the right ovary and the intestine, which mass Ercolani termed the "rudimentary testicle." The "self-moving spermatozoa" found on the walls of this sac were shown to be fat, the movements of which were due merely to the molecular movements of granules found often in animal tissue. The "alveolar or proligenous cells of the testicle" were the common alveolar vessels of adipose tissue.

Other investigators, G. Balsano Crivelli and L. Maggi, believed that they had found the testicles in these fatty deposits, which, Syrski tells us, are found in nearly all of his specimens, "more developed on the right side than on the left, sometimes fringed, as

shown in the illustration accompanying Ercolani's article, or with long borders, as shown in Prof. Maggi's illustration, but always of a structure which is, so to speak, typical of adipose tissue."

In 1874 R. Eberhard of Rostock described an "embryo of an eel" 24 millimeters long, with very large head and eye, swollen belly, and a yellow yolk sac. This specimen had supposedly come from the abdominal cavity of an eel and was one of about a thousand similar embryos contained therein.

In the same year Professor Münter, director of the Zoological Museum of Greifswald, after examining about three thousand eels without finding a male specimen, concluded that eels must necessarily reproduce by parthenogenesis. The eggs were laid in all probability at the bottom of the Baltic Sea from the middle of March to the middle of April, according to this investigator, and without fertilization developed into young eels one-half to two inches long, which migrated into fresh water about the beginning of May.

#### CAUSES OF ERRONEOUS BELIEFS

There are several logical reasons why this problem eluded solution for some two thousand two hundred and twenty-four years, since, for the first time of which we have record, it was considered by Aristotle. The general structure of the organs contributed much to the difficulty. The ovarian organs resemble those of a few fishes, the salmons and sturgeons for example, but are unlike those of the majority. They are two ribbons of tissue covered by tiny leaflets arranged transversally, on the outer surface, running almost the whole length of the body cavity to right and left of the intestinal canal. The spermatic organs are made up of two rows of very tiny lobes, about fifty on each side, connected by vasa deferentia running almost the whole length of the body cavity. In young eels of 200-300 millimeters or less the testicles have not yet attained the lobulated form and are similar to the ovaries of the female. The greatest length of the male specimens examined by Syrski was 430 millimeters, showing the males to be smaller than the females. The fact that the testicles are easy of differentiation only in specimens between 400 and 430 millimeters is one reason why they were not identified for so long a period.

That the American eel nearing a spawning condition seeks the open sea and does not feed for some time previous explains why specimens with completely ripe eggs have not been taken.

Some beliefs and superstitions concerning the procreation of the eel are not as far-fetched as they would seem at first glance, and we can explain their origin among unscientific observers. In Germany, Norway, and Sweden the eel-like fish *Zoarces viviparus* is called the Aal-mutter, or eel-mother. The young of *Zoarces*, as its name implies, are born alive and have constantly been confused with young eels. Thus we explain the "eel embryo" of Eberhard.

The idea of attributing the parentage of eels to other fishes has been carried beyond reasonable comprehension. Jacoby tells us that in Comacchio the fishermen believe even the changes in color and shape of the common mullet, *Mugil cephalus*, cause the differences in color and shape of eels, that eels copulate with water snakes, and—impossible as it may seem!—the Sardinian fishermen claim a beetle, *Dysticus roeselii*, as the "eel-mother." It has been pointed out that the confusion may have occurred from the finding of the aquatic hair-worm *Gordius* in this beetle, and because *Dysticus* and the eel often live in the same waters, the laughable relationship has been claimed.

A superstition concerning *Gordius* is that each individual is born from a horsehair dropped into water where a horse has been drinking. This means of reproduction has been stretched to include the eel, doubtless confused with the worm-body of *Gordius*.

No wonder centuries and centuries of questioning and speculation passed before science could dispel such superstitions—and indeed in some parts of the world today it has not succeeded.

#### LOCATION OF THE SPAWNING GROUND

With the truth finally established that the eel, just as other fishes, possesses ovaries and testes, the next obstacle to investigators seeking a solution of the eel question was the location of the breeding ground. Various writers had expressed the belief that spawning and fertilization took place offshore at depths varying from ten feet to the abysses of the ocean. Others maintained that they hatched in fresh water, as Robert B. Roosevelt, in 1877, who claimed his trout ponds in Great South Bay, Long Island, harbored breeding eels. To some the explanation of young eels coming upstream and overland on damp nights has not been sufficient to account for their presence far from the coast, often in landlocked water, and there are many today who scoff at an open sea migration theory.

Such stories as the following are prevalent among intelligent people, and it is a difficult task to convince them otherwise. In 1886 the Bulletin of the U. S. Fish Commission contained this statement by J. N. Sawyer, a Delaware eel-fisherman, "While some of them do (go to salt water to spawn), I do not think they all do, for in the winter of 1836 or 1837 we had what is known as the January flood in the Delaware, and wagonloads of eels of all sizes were found on low places after the water had subsided. One of my neighbors built a very tight dam, so constructed as not to permit any fish or eels to ascend. By this he overflowed a tract of land, and placing some eels in the pond left them to breed. After a period of fifteen or twenty years he placed an eel-weir in the dam and drew off the water to drain the pond for a meadow, catching barrels of eels of all sizes. These instances cited proved to me that eels do not all return to salt water to spawn, but spawn wherever they find suitable places in ponds or streams."

In spite of the popular tendency to discredit an exclusively-ocean spawning place, however, it was long ago noticed that in the fall of the year adult eels migrate downstream, and in the spring great numbers of tiny eels, about six to seven centimeters in length, appear from somewhere, swarming upon the coast and swimming upstream into fresh water, back over the course their parents took outward to the sea. Smaller young were never seen and it was not until 1896 that their dissimilarity to the adult was guessed. In that year Grassi and Calandruccio published the amazing discovery that the peculiar ribbon-like fish described by Kaup in 1856 as *Leptocephalus brevirostris* was indeed the larva of the European eel, and further answered the question of their absence inshore by declaring that the eel must spawn at great depths, the leptocephali normally developing and living at this level. Their presence at the surface in the Straits of Messina was explained by the action of currents churning up the bottom layers of water. The probability of development very far below the surface has not been confirmed, and many workers at the present time are doubtful of its occurrence in any eels, all evidence strongly pointing against larval life at such depths for the American and European eels at least.

The greatest advances toward an understanding of the breeding places of the eel have been made by the Danish Commission for the Exploration of the Sea under the directorship of Johs. Schmidt.

From 1904 until the present Schmidt has been working in masterly fashion and the conclusions of his latest report sums up briefly his achievements in the life history of the European eel. "During the autumn months the silvery eels leave the lakes and rivers and move out into the sea. Once beyond fresh-water limits the eels are, in most parts of Europe, outside our range of observation. Exceptions are, however, found, as in the case of the Danish sounds and belts and adjacent waters, which are passed by great quantities of eels on their way to the Atlantic, and form the site of important fisheries about October. In the western part of the English Channel trawlers may, toward the end of the year, occasionally bring up a few big specimens in their nets, but after this the last trace of the eel on European ground is lost. No longer subject to pursuit by man, hosts of eels from the most distant corners of our continent can now shape their course southwest across the ocean, as their ancestors for unnumbered generations have done before them. How long the journey lasts we can not say, but we know now the destination sought: A certain area situate in the western Atlantic, south-east and north of the West Indies. Here lie the breeding grounds of the eel.

"Spawning commences in early spring, lasting to well on in summer. The tiny larvae, 7-15 mm. long, float in water layers about 200-300 meters from the surface, in a temperature of about 20° C. The larvae grow rapidly during their first months, and in their first summer average about 25 mm. in length. They now move up into the uppermost water layers, the great majority being found between 50 and 25 meters or at times even at the surface itself. Then they commence their journey toward the shores of Europe, aided by the eastward movement of the surface water itself. During their first summer they are found in the western Atlantic (west of 50° long. W.). By their second summer they have attained an average length of 50-60 mm., and the bulk are now in the central Atlantic. By the third summer they have arrived off the coastal banks of Europe and are now full grown, averaging about 75 mm. in length, but still retaining the compressed, leaf-shaped larval form. In the course of the autumn and winter they undergo the retrograde metamorphosis which gives them their shape as eels and brings them to the elver stage, in which they move in to the shores and make their way up rivers and watercourses everywhere.

The average age of the elvers in spring is about 3 years. Many individuals, especially males, keep to the brackish water in lagoons or estuaries; others, especially females, move far up the streams they have entered and may in the course of their wanderings penetrate far into the interior of the Continent. In Switzerland, for instance, considerable quantities of eels occur, and specimens have been taken there in waters at an altitude of 3,000 feet above the level of the sea. The eels utilize their sojourn in fresh water to feed and grow big, but the duration of their stay here varies greatly, according to sex, climate, and quantity of food, ranging from about five to about twenty years or more. All the large eels are females; the males seldom exceed 45 cm. in length. During its period of growth the eel is of a yellowish or greenish color, with no metallic luster; these growing eels are generally termed "yellow eels." When they have reached the stage where the migratory instinct begins to assert itself the desire for food, otherwise voracious, is lessened, the body takes on a metallic sheen, and the pectorals become black and pointed. In this guise the eels are termed "silver eels," their flesh is very firm and rich in fat, and they are thus well equipped for entering upon their second and last great journey, this time back to the breeding grounds across the ocean."

Fig. 115 (p. 305) was made by Schmidt to show the distribution of the European eel and the American eel over the breeding grounds, the single lines denoting the former, the dotted lines the latter species. The heavily drawn innermost curve embraces the spawning areas; no leptocephali larger than 10 millimeters have been found within the ten millimeter curve, and so on, until the 45 millimeter curve, beyond which no larvae have been taken.

The hardest phase of the question to explain, and one which was insolvable to most inquirers, was the total absence of any European eel young along the American coast and of American eel young in European waters, in spite of the close proximity of the breeding grounds. Schmidt answers it thus: "In the case of the American eel, the pelagic larval stage is terminated in about one year; consequently the larvae have not time to make the journey to Europe, the distance being more than they can cover in that period. It is otherwise with the European eel, which takes nearly three times as long over its larval development, as a result of which practically all of them are far away from the western (American) portion of the Atlantic when the time comes for them, as elvers, to seek the coasts.

"We can thus indicate both a geographical and an ethological cause for the distribution of the two species of fesh-water eels. The former lies in the fact that *Anguilla rostrata* has its center of production somewhat farther west and south than *Anguilla vulgaris*. The latter is the different duration of the pelagic migratory stage. These two facts, in conjunction with the ocean currents as an aid to transport, and later—once the earliest stages of development are passed—the active movements of the larvae themselves, must be regarded as the causes which lead the two Atlantic species of eels to find each its own side of the ocean, despite the close proximity of their breeding grounds."

When we consider the fallacious beliefs regarding the various phases of the life history of the eel, which seem ludicrous in the light of this present knowledge but which were held with all good faith by foremost thinkers of their time, it is with hesitation that I dare associate the name of the American eel with the four eggs taken by the "Arcturus Expedition." As Ercolani in his essay "*Del perfetto ermafroditismo delle Anguille*" began: "the author this day appears before the academy with fear and trembling, since he intends to present something new regarding a question which has been the rock on which the vessels of so many distinguished scientists have foundered."

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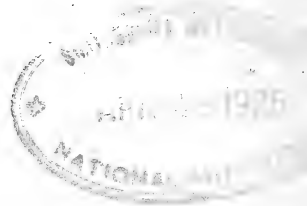
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# STUDIES ON THE BODY-FORMS OF FISHES\*

BY WILLIAM K. GREGORY

(Figs. 117-155 incl.)

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## INTRODUCTION

The Arcturus Oceanographic Expedition of the New York Zoological Society in 1925 made large collections of deep-sea and pelagic fishes in the Sargasso Sea and in the Central Pacific, and of inshore fishes in the Galapagos Archipelago and Cocos Islands. This collection has provided the material for the present investigation, which deals with the body forms and fins of fishes.

During the expedition the taxonomy, anatomy, osteology and food-habits of the fishes collected were constantly studied by the Director and myself, with the able assistance of Miss Ruth Rose, Miss E. S. Trotter, Mrs. Charles J. Fish and Miss Lillian Segal. The movements and habits of inshore fishes in their native environment were studied by us during many descents in our diving helmets in the Galapagos and Cocos Islands, while pelagic and a few deep-sea forms were studied alive in the aquaria on board the ship.

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The locomotor apparatus of fishes is inadequately treated even in the best text-books of ichthyology. It is true that these works contain elaborate and detailed morphological descriptions of the parts that compose the locomotor apparatus, but they give little as to its mode of functioning and nothing as to the underlying mechanical and biological principles that condition its construction. Even works that touch upon the subject from the viewpoint of mechanics, such as Marey's *Animal Mechanisms*, while containing a few valuable facts, do not give a comprehensive picture of the subject as a whole.

On the biological side the clearest general account of the locomotion of fishes which I have been able to find is that by O. Abel in his excellent work, "*Grundzüge der Palaeobiologie der Wirbeltiere*" (1912, pp. 104-113); but Abel, Dollo, Schlesinger, Whitehouse, Schmalhausen<sup>1</sup> and other authors whose papers are listed under "Locomotion" in Dean's *Bibliography*, volume III, have been concerned mainly with the various forms of caudal fins and with such broad categories of body forms as the depressed, the fusiform, the disciform (Abel), the cheloniform (Abel), the tæniiform (Abel) and the sagittiform (Schlesinger). But these papers do not treat the subject from the experimental side and have very little indeed to say about the mechanisms and mechanical reactions involved.

On the experimental side Houssay (1909-1914) has shown very clearly the molding effect of water pressure upon plastic bodies drawn through it at various speeds, these bodies gradually approaching the standard fish type as the experiment was repeated. He also succeeded in stabilizing the flight of fish-like models by the appropriate placing and tension of artificial fins. Monoyer (1866), Mayer (1886), Duges (1905), and R. C. Osburn (1906) started a very interesting line of work by removing different fins and observing the results on the locomotion of the fish. Their work has been corrected and greatly extended by C. M. Breder, Jr., of the New York Aquarium. He (1926) has attacked the subject from the four converging paths of taxonomy, body form, physiology (adaptation) and physics and has constructed mechanical models to illustrate the modes of locomotion of eel-like and of stiff-bodied fishes.

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<sup>1</sup> Schmalhausen's important paper "On the Functions of the Fins of the Fish (Preliminary Note from "*Revue Zoologique Russe*," not dated) was received in January 1925, after the completion of the present paper.

It is this synthetic treatment I think, which has brought Breder's long-continued and ingenious experiments to the goal of scientific investigation; for he has repeatedly succeeded, by analysis of the body form and fin characters of a preserved specimen, in inferring with fair degree of accuracy the modes of locomotion of that fish in life.

Before I left New York on the *Arcturus* expedition Mr. Breder gave me a copy of his then unpublished manuscript on the locomotion of fishes for use in my own studies on the body forms of fishes. The very frequent reference to Mr. Breder's results in the following pages will indicate the extent of my indebtedness to him.

Breder classifies the movements of fishes that progress by lateral undulations under three successive and intergrading classes:

1. The anguilliform type, exemplified in eel-like fishes, with the body elongate, flexible, thrown into a succession of "sine curves," with increasing amplitude posteriorly.

2. The carangiform type, with body movements of intermediate character, to which the vast majority of fishes conform.

3. The ostraciiform, exemplified in the trunk fishes, in which the body itself is rigid and swings from side to side around the peduncle as a fulcrum.

The object of my present and subsequent papers is to supplement Breder's fundamental work by providing a review of the body forms and fins of recent and fossil fishes, with special reference to the proportions and positions of the various parts. The system of describing the body form of fishes with reference to certain partly inscribed rectilinear figures, is apparently new. A search of the literature, at least, has failed to reveal any author to whom I could gladly pay the tribute due to priority.

Ichthyologists have long used the ratios of length and breadth of the different parts of a fish as diagnostic specific characters. In the present studies such ratios and indices will be used, not for this purpose but for the purpose of contrasting and describing the different body forms. With the assistance of Miss Elizabeth S. Trotter, over twelve thousand such measurements, representing over two hundred species of fishes were made in the laboratory of the *Arcturus*. These measurements will, it is planned, be considered in subsequent papers of this series.

## THE FISH AS AN ANIMAL MECHANISM

*The locomotor apparatus: its purpose.*—The locomotor apparatus of a fish is obviously one of the chief means by which it plays the game of life, the objects of which are to avoid death, to seek and find life in food and oxygen, to give life to descendants. In order to be successful in these objects, the typical fish must perpetually adjust itself to a highly unstable environment. Wholly sessile animals stay in one spot and let the environment sweep past or through them, while planctonic forms drift about with the currents, but, by means of an elaborate locomotor apparatus, a typical fish navigates with marvellous agility in shifting waters.

*The locomotor apparatus and gravity.*—The entire locomotor apparatus is therefore orientated primarily with reference to the direction and force of currents of water, which are caused directly or indirectly by the force of gravity, the body form being such as to head upstream with the minimum expenditure of energy necessary to maintain the position of the fish and to prevent it from being swept down stream. Thus the movements of a typical fish, in the long run, are at right angles to the direction of gravity and tangent to the earth's surface. Bilateral symmetry, dorso-ventral differentiation and the elaborate arrangements for maintaining the body in an upright position are accordingly all adjustments to a universal cosmic force. The same universal force also produces pressure in the medium in which the fish lives, and the complex arrangement of wedges, fulcra and levers of a fish's body, relate chiefly to the efficient cleavage of the gravity-pervaded medium. It is for this purpose that energy must be captured from the environment.

*Elements of the locomotor machinery.*—The striped muscle fibre, which is the unit of the locomotor machinery, is a sort of internal combustion engine. Combustion is effected in every cell of this engine by means of the oxygen which is delivered at the right spot by the hæmoglobin of the blood. The iron in the hæmoglobin, which gives the red color, has the property of taking oxygen from the medium, holding it loosely, without combining with it, and delivering it to the tissues. During this operation the iron itself is not consumed, so that an extremely small quantity may be used again and again. A fish, therefore, like an annelid, a nemertean worm, or a mollusc, is an animal that has selected iron for its oxidizing agent.

A fish has its locomotor engines arranged at right angles to the direction of gravitation, in bilateral symmetry on either side of the mid-line, along which is a more or less jointed stiffening axis, or vertebral column. The controlling and coördinating apparatus or cerebro-spinal nervous system, while arranged segmentally along the body, culminates in a head or central control station at the front end, that is the end towards which the fish moves.

The red muscle fibres of the lateral body muscles are placed more or less horizontally in vertical zig-zag rows, bounded fore-and-aft by transverse connective tissue septa. Each muscle fibre is covered by a sheath which is fastened at either end to the zig-zag septum. A single zig-zag row is called a myomere or myotome.

*First principles of Vertebrate locomotion.*—The serially timed contractions of the myomeres on opposite sides bend the body from side to side and cause the lateral undulations which produce a forward movement of the body in the water. Owing to the zig-zag arrangement, the myomeres form a vertical series of cones with the apices directed forward. The sharper the angulation of the zig-zag, the further forward the apices of the cones extend, the greater the number of the myomeres in a given transverse plane and the more nearly horizontal is the combined pull of the lateral muscle masses (Greene).

According to Breder (1926) a long-bodied fish starts a wave going backward by jerking the head slightly to one side, through the contraction of some of the myomeres on that side. At the same instant the postcranial part of the body swings still less toward the same side. The whole body then pivots on the head and forms a long sweep ending behind in the tail fin. The body oscillates like a many-jointed pendulum, the forward movement as a whole somewhat resembling the swaying motion of a skater. The bending of the body produces a pressure of water on the posterior side of the backwardly-travelling concavity. In order to secure a forward resultant, however, through the contraction of successive myomeres, the concavities must be passed backward faster than the fish moves forward (Breder). As the concavities are passed backward the amplitude of the undulations along the back bone increases. This gives greater force and a more direct thrust to the posterior end of the body, and demands less lateral movement of the head (Breder). For these and other reasons the greatest cross section of the body is



always nearer the front end (Parsons); and it is shown below that the entering angle is greater than that of the run.

Coördination and timing of the contractions on opposite sides of the body is probably effected by the crossing over of a portion of the nerve fibres from each segment to the opposite side of the brain.

*The fins as accessory locomotor organs.*—Median and paired fins are not primary but accessory organs of locomotion, originally used for balancing and steering only. Many lines of evidence support the view that they have arisen, not as continuous folds of skin, but from local projections of the body-wall serving as keels. Thus all fins may be regarded as both fulcra and levers used primarily in balancing and turning various parts of the body, and sometimes (in the more specialized forms) as paddles.

The most primitive fins are those of elasmobranchs, which consist essentially of processes of the body-wall including prolongations of the body muscles, which warp the fin fold. The supporting cartilaginous rods are local stiffenings of the connective tissue septa, occurring in the loci of the greatest stress between opposing muscle sheets. The surface periphery of the fin in elasmobranchs is covered with horny rays (*ceratotrichia*) which are reduced or lost in the higher fishes. In general, the surface of the fins is less differentiated, more homogeneous in the sharks and their allies than in the typical bony fishes.

The dermal rays of the fins of higher fishes have been derived by a fusion of long ganoid scales and by subsequent emphasis of the bony substratum and reduction of the surface layers, as fully shown in the Palæozoic ganoids of the family *Palæoniscidæ*. It is also well known that spiny rays were later derived by the fusion of the distal segments or joints of the rays.

The extent to which the fins could be erected or depressed, stretched or relaxed was greatly enhanced by having stiff dermal rays alternate with elastic skin. This umbrella-like arrangement, which is not even foreshadowed in the fins of elasmobranchs, and is but poorly developed in the older ganoids, is one of the basic patents, so to speak, of the later ganoids and typical teleosts. Owing to the extensibility of the fins in these forms, a relatively large fin can be tucked away when not needed, as in straight forward movements, without impeding the movement as it would if it were permanently erected like the dorsal fin of a shark. Again

it can be suddenly extended when a change of direction or stopping of movement is desired. Consequently the fins of normal-bodied teleosts are generally larger than those of elasmobranchs and their turning and stopping movements are quicker. The later teleosts are thus better able to cope with rapidly shifting currents, and are as a rule, more efficient both in pursuit and in flight. This fact has no doubt contributed materially to the success and dominance of the teleosts in competition with their more conservative relatives of the ganoid group.

*The caudal fin.*—The shape and position of the fins vary almost infinitely according to the cross sections of the body at different planes and according to the different functions assumed. In general the caudal fin is an active and very adaptable rudder, usually capable of initiating its own series of undulations, in both vertical and horizontal planes. Houssay (1914) has shown that a heterocercal caudal fin also acts as a stabilizer, which prevents the body from rolling over. In very long bodied fishes that swim chiefly by lateral undulations the caudal fin becomes very small or reduced to a point. On the contrary, in very short, stiff bodied forms, such as the trunk fishes, the tail is used in sculling. The tail is excavated posteriorly in swift swimming fishes, because the excavated area is the locus of greatest pressure of the two lateral columns of water that have been displaced by the fish in its forward movement (Nichols). On the other hand, a convex tail, while subject to this pressure, has a firmer fulcrum to push against. A narrow caudal peduncle, joined with a forked or crescentic tail, is found in the carangids, mackerels and other fishes that swim very easily for long distances; again a wide fleshy peduncle and convex tail is found in many fishes that make sudden powerful rushes or leaps.

*The dorsal fin.*—The dorsal fin is primarily a keel, often erectile and collaborating with the pectorals in maintaining an upright position. The same is true of the anal. When elongated both the dorsal and the anal fins can make their own undulations, which check or modify the various effects of the pectorals and caudals. In deep bodied fishes (such as balistids) the elongate dorsal and anal, opposing each other on the posterior slopes of the body, become important in slow forward movements, and also prevent loss of vertical balance.

*The pectoral fins.*—The pectorals are primitively extended in a horizontal plane, as in the sharks, which have relatively broad depressed heads and need strong lateral and vertical keels. Turning is effected by slightly depressing one pectoral and raising the other. In some fishes the pectorals tend to take the initiative over the body muscles, and moderate forward movements are effected by them; as in teuthids, balistids and wrasses.

A subhorizontal position of the pectorals is found in the lower ganoids and teleosts which retain the mesocoracoid arch. These have the pectorals inserted low down near the ventral line. Very early in the history of the teleosts the pectorals acquired the ability to fold back along-side the body during swift forward movements, which they served to check by being suddenly thrust outward. In the higher teleosts the anterior base of the pectoral has been rotated upward so that it lies on the upper border of the fin. Such pectorals are usually inserted higher up on the body and when they are brought forward they oppose a wider surface to the water and are more effective in checking or directing movement. In these cases the mesocoracoid arch is lost (as in the *Haplomi* and *Acanthopterygii*) and the base of the fin is nearly vertical instead of horizontal.

In many higher teleosts the water is squirted from the gill slits with such force as to become an important factor in forward locomotion (Breder). In small nervously moving fishes the pectorals keep up a rapid fan-like vibration which may either check the backward thrust from the gill openings or suddenly augment a quick jerk to one side.

*The pelvic fins.*—The pelvic fins were originally horizontal balancers that served to steady the base of the tail. They are accordingly abdominal in position in the long bodied elasmobranchs as well as in the lower ganoids and teleosts. But the higher teleosts have probably all been derived from short bodied *Beryx*-like fishes in which the pelvic fins had been shifted forward to a pivotal thoracic position. By tying the pelvic arch on to the base of the pectoral arch the stability of both the pectoral and the pelvic fins was greatly improved and very possibly the lateral sweep of the caudal end of the body could be increased without adding to the length. This combination of the pectoral and pelvic fins no doubt also improved the speed of turning and stopping movements; the

increased stability of this arrangement very probably made possible an increase in total fin area, as it seems to be a fact that in the average *Acanthopterygii* the total fin area is greater than in the average *Isospondyli* and much greater than in the primitive ganoids of the families *Palæoniscidæ*, *Semionotidæ*, *Eugnathidæ*.

*The thrusts of the myomeres and fins.*—The thrusts of the lateral myomeres are transmitted to the tail through the connective tissue septa, ligaments and tendons as well as by way of the vertebral column. The thrusts of the dorsal fins are not, however, transmitted toward the column. These levers are embedded in a muscle layer, which is tied on to the occiput and has no direct bony connection with the column; the pull of this muscle mass being independent of that of the dorsal muscles of the column. Similarly the anal fin in primitive types is not directly connected with the column, and both dorsal and anal fins have a pulling rather than a pushing effect, their chief office being to pull the anterior end of the body toward the side to which they are deflected. It is only in highly specialized forms, such as balistids and puffers, that the dorsal and anal become paddle-like and tend to push the body forward. Even the tail has a pulling or deflecting effect as well as a pushing movement. In fact the pulling rather than pushing effect probably predominates in all the fins of primitive fishes.

*The skull as entering wedge.*—The pulling and pushing stresses of all the fins and of the column are transmitted more or less indirectly to the skull, which forms the entering wedge of the body and must withstand the opposing thrusts from the water in front and from the whole muscular body behind. From it are movably suspended and articulated the primary upper and lower jaws, the opercular system, the strong and complex branchial skeleton, the pericardial chamber, and the whole pectoral girdle, which in turn transmits to it the thrusts from the great lateral body muscles; while in its deep recesses the brain, the cranial nerves and the organs of equilibration, feeling, sight and smell find secure lodgement.

The skull is, indeed, a masterpiece of architectural engineering. Its basioccipital forms the base, while the exoccipitals and supra-occipital form the limbs and keystone of a rear transverse arch, while the ossified olfactory capsules and the curved top of the skull form a strong fore-and-aft arch. On the lower side, between the

orbits, another fore-and-aft arch, or keeled trough, formed by the vomer and parasphenoid bones, ties the forward wedge of the skull to the base of the occiput and forms a chamber for the strong recti muscles that move the eyes. The eyes are placed in a well protected position on either side of the median longitudinal arch and between the massive olfactory capsule in front, and the still larger brain-case behind.

*Entrance and run.*—In conclusion the locomotor apparatus of a fish may be conceived as consisting of two overlapping parts, conforming, as a whole, to stream-line requirements:

1. An entrance, or wedge-like portion, the passive part of the mechanism, comprising the head, throat and abdomen, and thus including: (a) the skull, enclosing the automatic control or navigating mechanism, (central nervous system, sense organs); (b) the circulatory or fuel-distributing system; (c) the respiratory or oxygenating and oxidizing system, and its skeletal supports; (d) the ingestive or fuel-securing apparatus (including the primary and secondary upper and lower jaws and their dentition); (e) the digestive or fuel-preparing apparatus (the digestive tract and its glands); (f) the reproductive system; the whole being surrounded by an insulating or protecting cover of skin, scales, surface bones etc.

2. The run, or sloping surface behind the greatest cross-section of the body, a smooth, flexible covering, enveloping the abdomen, back sides, and fins, forming the surface along which the displaced water flows backward.

The propelling apparatus is located chiefly in the run. It includes the muscular substratum of the run, the connective tissue septa, the ribs, the backbone and its apophyses, the fins and their supports and the whole caudal part of the body.

#### THE BODY-FORMS OF FISHES AND THEIR INSCRIBED RECTILINEAR FIGURES

The body forms of normal fishes in the lateral view have certain relations to quadrilateral figures of varying proportions that may be inscribed within them. The anatomically constant points of reference and axes of these figures may be named as follows:

1. *prosthion* (*P*): the most anterior point of the snout (or of either jaw when the latter protrudes beyond the snout).
2. *pygidion* (*p*): the mid-point of the caudal peduncle. The line

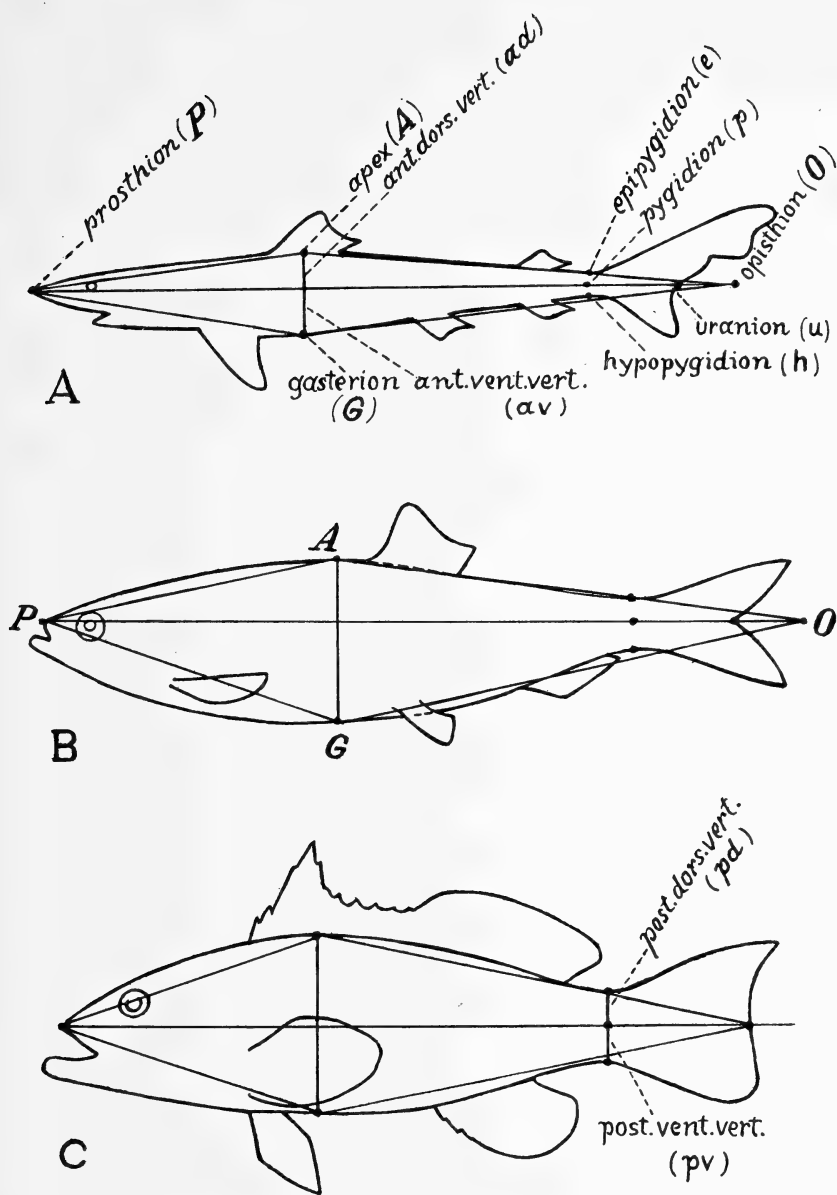


Fig. 117. The body-forms and fins of typical fishes, in their relations to quadrilateral figures. A, Shark (*Catulus uter*); B, Herring (*Clupea harengus*); C, Serranid (*Paralabrax maculatofasciatus*). Outlines after Jordan and Evermann.

from the prosthion through the pygidion is called the *horizontal* or anteroposterior axis.

3. *apex* (*A*): the summit of the dorsal curvature. The vertical from the apex to the horizontal is here called the *antero-dorsal vertical* (*ad*).
4. *gasterion* (*G*): the lowest point of the ventral contour. The vertical from the gasterion to the horizontal is called the *antero-ventral vertical* (*av*).
5. *opisthion* (*O*): the point of intersection of the horizontal with a line drawn from the apex through the epipygidion.
6. *epipygidion* (*e*): the lowest point on the dorsal border of the caudal peduncle above the pygidion.
7. *hypopygidion* (*h*): the highest point on the ventral border of the caudal peduncle, often immediately below the pygidion. The vertical from the pygidion to the epipygidion is the *postero-dorsal vertical* (*pd*); that from the hypopygidion to the horizontal is the *postero-ventral vertical* (*pv*).
8. *uranion* (*u*): the point where the posterior border of the tail crosses the horizontal.

The four sides or boundaries of the quadrilateral are:

1. *Antero-dorsal* (*PA*) from prosthion to apex.
2. *Postero-dorsal* (*AO*) from apex to opisthion.
3. *Antero-ventral* (*PG*) from prosthion to gasterion.
4. *Postero-ventral* (*GO*) from gasterion to opisthion.

The angles of the quadrilateral (Fig. 118C) are named as follows:

1. *Anterior or entering angle* (*APG*): at the prosthion between the antero-dorsal and antero-ventral slopes. This angle may be divided into two parts, an antero-dorsal ( $\alpha$ ) and an antero-ventral angle ( $\alpha'$ ).
2. *Dorsal angle* (*PAO*): at the apex between the antero-dorsal and the postero-dorsal. This is subdivided by the antero-dorsal vertical into two usually unequal angles *PAG* and *OAG*.
3. *Posterior angle* (*AOG*): at the opisthion between the postero-dorsal and the postero-ventral slope. The posterior angle, or angle of the run, includes a dorso-posterior angle ( $\beta$ ) and a ventro-posterior angle ( $\beta'$ ).
4. *Ventral angle* (*PGO*): at the gasterion between the postero-ventral and the antero-ventral boundaries. The ventral angle is divided by the antero-ventral vertical into two angles *PGA* and *OGA*.

When the dorsal vertical and ventral vertical are in line with each other the single vertical diameter divides the quadrilateral into two acute-angled triangles, one pointing forward (*APG*), the other backward (*AOG*), the vertical diameter being the common

base. Usually the dorsal vertical lies in the anterior half of the horizontal and the entering angle (apex of the forwardly directed triangle) is therefore greater than the posterior angle. Similarly the horizontal forms the common base of dorsal (*APO*) and ventral (*PGO*) triangles, the apices of which usually become more obtuse as the horizontal exceeds the vertical or verticals in length.

The method of drawing the quadrilateral is as follows:

First the prosthion (*P*) and the pygidion (*p*) are determined and the horizontal (*Pp*) is drawn through them. Then the apex (*A*) is determined, it being at the greatest height above the horizontal. The gasterion (*G*) is then fixed and the antero-dorsal (*PA*) and antero-ventral (*PG*) boundaries drawn.

The postero-dorsal boundary (*AO*) from the apex to the epipygidion is then drawn. It is usually tangent to the general slope of the back. The opisthion is determined by the intersection of the postero-dorsal boundary with the horizontal. The postero-ventral boundary is then drawn by joining the opisthion with the gasterion.

The opisthion usually lies behind the uranion, or point where the posterior border of the caudal fin intersects the horizontal, especially in large-tailed fishes. In this case, the posterior part of the quadrilateral lies entirely behind the body contour. When the body is elongate and tapering posteriorly and when the vertical spread of the tail becomes very small, the opisthion and the uranion tend to coincide and the posterior contour of the body coincides with that of the quadrilateral.

The distance (*X'*) of the opisthion behind the pygidion is evidently (Fig. 118D) a function of the dorso-posterior angle ( $\beta$ )

$$\text{Now } \tan \beta = \frac{pd}{X'} \text{ and } \tan \beta' = \frac{ad-pd}{X};$$

$$\text{hence } X' = \frac{X \, pd}{ad-pd}$$

That is the distance of the opisthion behind the pygidion (*X'*) is directly proportional to the product of the posterior dorsal vertical (*pd*) by the distance between the anterior and posterior verticals (*X*); and, inversely proportional to the difference between the antero-dorsal and postero-dorsal verticals. As the difference between the antero-dorsal and postero-dorsal verticals becomes



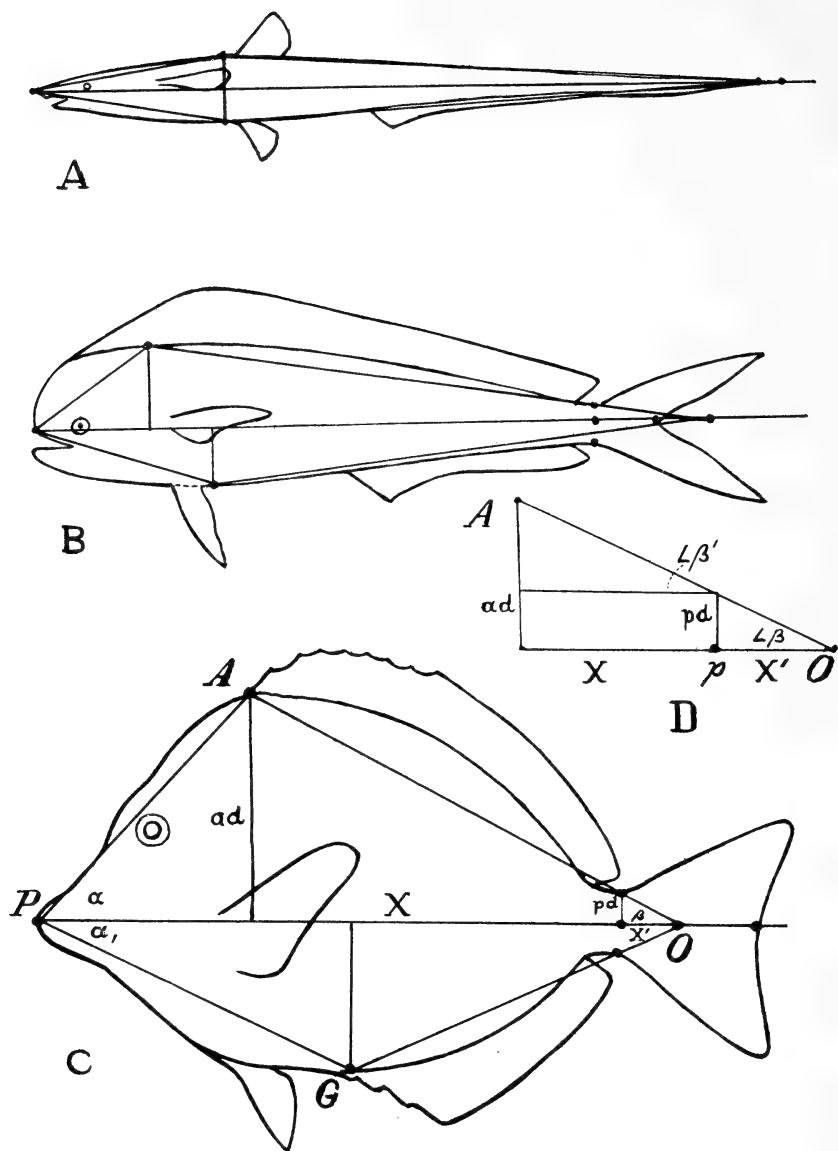


Fig. 118. The body-forms and fins of specialized fishes. A, Deep-sea fish, *Aldrovandia macrochir*; B, Dolphin (*Coryphæna hippurus*); C, Surgeon fish (*Xesurus punctatus*); D, Geometric relations of the opisthion (o) and pygidion (p) of the anterior and posterior dorsal verticals (ad, pd). Outlines after Jordan and Evermann.

smaller, compared to the distance between them, the opisthion moves backward toward infinity. (Fig. 119B.) Again, if  $X$  be relatively great  $X'$  will also be large, as in certain Percidæ (Fig. 149A).

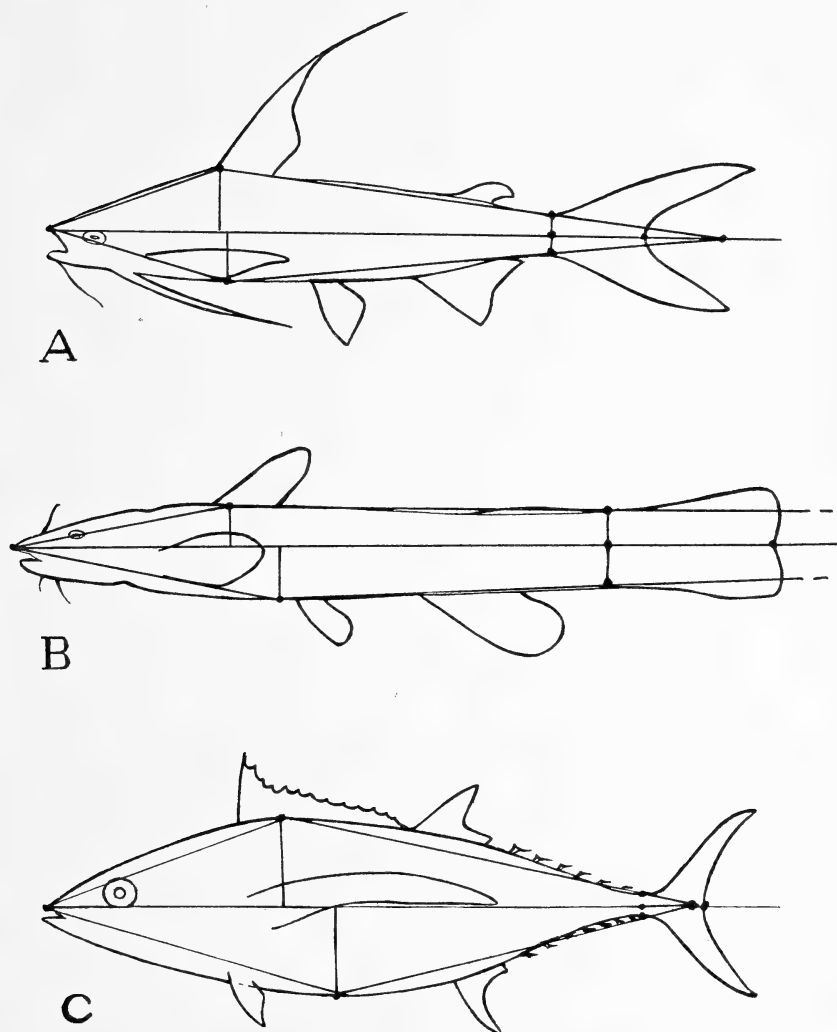


Fig. 119. Varying relations of the opisthion to the uranion. A, *Opisthion posturanic* (*Felichthys marinus*); B, *Opisthion posturanic approaching infinity* (*Schilbeodes insignis*); C, *Opisthion preuranic* (*Germo alalunga*). Outlines after Jordan and Evermann.

The horizontal divides the body-form into upper and lower moieties, which in different series of related genera appear to have some degree of independence of each other. Thus starting from normal forms with subequal dorsal and ventral moieties we may find forms with a high back and shallow abdomen (in which the dorsal vertical exceeds the ventral vertical), as in the buffalo carps (*Ictiobus*), Haemulidae, Sparidae, or forms with a shallow back and deep abdomen (Fig. 127). In the Carangidæ both forms occur (*Selene*, with deep back and shallow abdomen, *Chloroscombrus* with shallow back and deep abdomen). The anterior and posterior pairs of triangles are less independent of each other than the dorsal and ventral sets, since a forward displacement of the verticals tends to decrease the posterior and increase the anterior angles.

The ventral, dorsal and front views likewise have definite relations to inscribed rectilinear figures, which are usually quadrilaterals. In the ventral view (Fig. 120A) the four principal points of reference are the prosthion (*P*) and the hypopygidion (*h*), defining the longitudinal axis, and the opposite points of the greatest transverse diameter which may be named the dexterion ( $\delta$ ) and the aristerion ( $\alpha$ ). In the front view the four points of reference are the prosthion and the apex, fixing the vertical, and the dexterion and aristerion fixing the transverse diameter. In the top view the four points of reference are the prosthion, epipygidion, dexterion and aristerion. In the back view the axes would be drawn through the apex and gasterion, dexterion and aristerion.

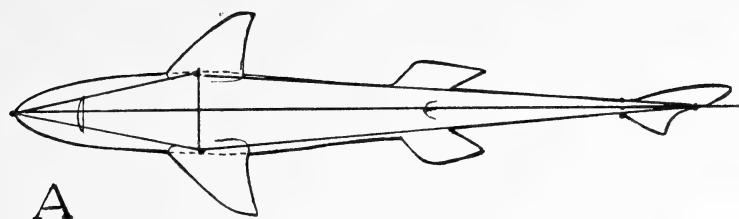
The principal kinds of rectilinear figures that may be drawn within or near to the body forms of fishes in the side view are as follows:

1. Inscribed rectilinear figures quadrilateral:

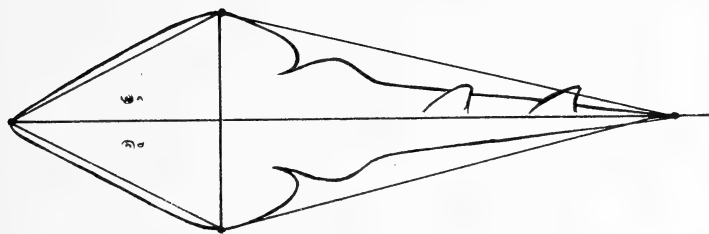
- (a) Dorsal and ventral verticals in line: many sharks (Fig. 117A), sturgeons (Fig. 124B), Protospondyli, Isospondyli (Fig. 117B), Ostariophysi, Scombridæ, *Micropterus dolomieu*, etc.
- (b) Ventral vertical behind dorsal vertical (Figs. 125A, 118B, C, 121, 126B, D).
- (c) Ventral vertical in front of dorsal vertical (Figs. 125C, 122B, 138A, 148B, C).

2. Inscribed rectilinear figure pentagonal.

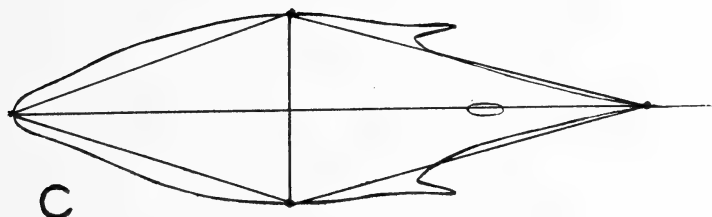
When the ventral fins are shifted forward below the pectorals



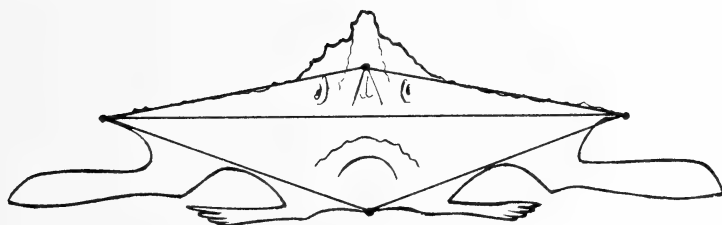
A



B



C



D

Fig. 120. The bounding quadrilateral figures in the ventral, dorsal and front views. A, Shark (*Squalus acanthias*), ventral view; B, Rhinobatus (*Rhinobatus lentiginosus*), dorsal view; C, Trunk-fish (*Lactophrys bicaudalis*), ventral view; D, Bat-fish (*Ogcocephalus vespertilio*), front view. Outlines after Jordan and Evermann.

the simple quadrilateral is often transformed into a pentagon, as in many Acanthopts (Figs. 140B, 151C).

The variable relations of the parts of the rectilinear figures to each other, of the form and position of the median and paired fins, etc., are given below in the list of variable factors of body form, which also contains the new descriptive terms used in the present paper.

#### CONSTANT FACTORS OF BODY-FORM

The more obvious constant relations of the parts of the quadrilaterals to each other, and to the parts of the body, are as follows:

1. Vertical diameter or diameters dividing the quadrilateral into anterior and posterior triangles (Fig. 117).
2. Horizontal dividing the quadrilateral into the dorsal and ventral triangles (Fig. 117).
3. Dorsal and ventral angles of dorsal and ventral triangles obtuse and becoming more obtuse as horizontal exceeds vertical (Fig. 118).
4. Anterior and posterior angles of anterior and posterior triangles acute; becoming more acute as horizontal exceeds vertical diameters (Fig. 118).
5. Ventral angle of ventral triangle (*PGO*) exceeding dorsal angle (*PAO*) of dorsal triangle as ventral vertical diminishes or as dorsal vertical increases (Fig. 118, B, C).
6. Entering angle (*APG*) greater than posterior angle (*AOG*) and increasing as anterior verticals (*ad*, *av*) approach prosthion. (Fig. 121.)
7. Caudal angle (inclination of dorsal and ventral borders of caudal to horizontal) in homocercal types usually exceeding entering angle.
8. In homocercal caudal fins angles of dorsal and ventral borders to postero-dorsal and postero-ventral boundaries of quadrilateral typically equal (Fig. 119A, 124C).
9. Convexity of dorso-anterior slope (Fig. 121) tending to increase directly with the following factors either singly or in combination:
  - (a) antero-dorsal vertical exceptionally far forward, as in *Coryphæna* (Fig. 118B), or exceptionally high, as in sparids (Fig. 126D) and many carangids;
  - (b) eye very large and at the same time far forward and high, as in *Alticus atlanticus*, *Upeneus maculatus*, *Mycotphum opalinum* (Fig. 121);
  - (c) mouth small and not directed upward, as in many

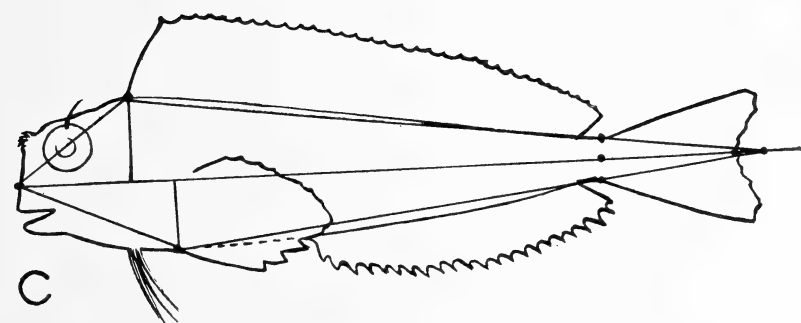
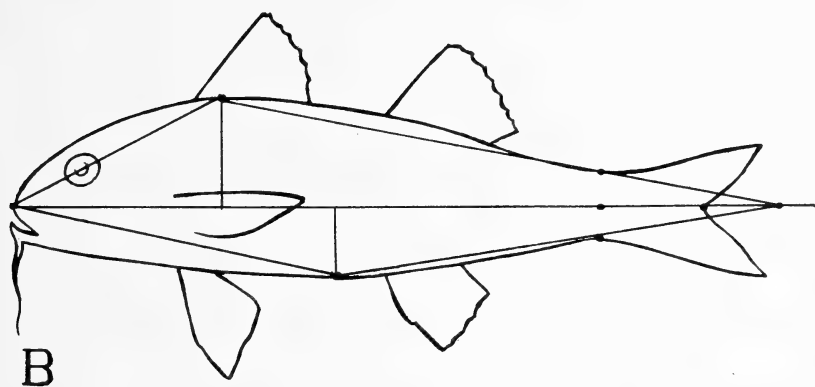
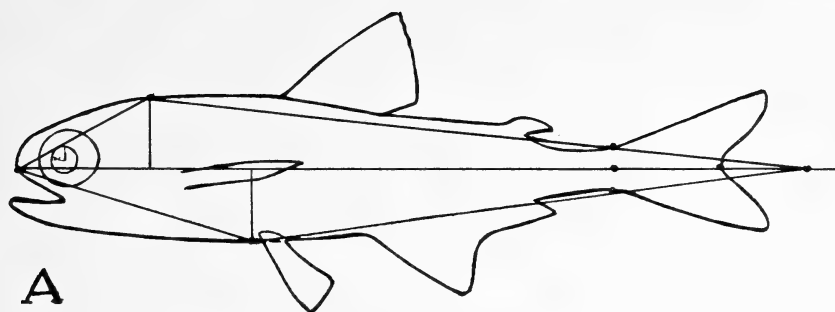


Fig. 121. Fishes with convex dorso-anterior slope and high entering angles. A, Myctophid (*Myctophum opalinum*); B, Mullet (*Upeneus maculatus*); C, Blenny (*Alticus atlanticus*). Outlines after Jordan and Evermann.

cyprinids, mullids, carangids, sciænids, or mouth inferior in position (certain mullids);

(d) snout very short as in cyprinids, blennies, mullids.

On the other hand, a flat, concavo-convex or retreating forehead (Fig. 122) is frequently associated with one or more of the following conditions:

(a) antero-dorsal vertical displaced backward, as in pikes (Fig. 122A), *Bathypterois*;

(b) eye very small, as in many sharks, sturgeons, pikes, barracudas, catfishes;

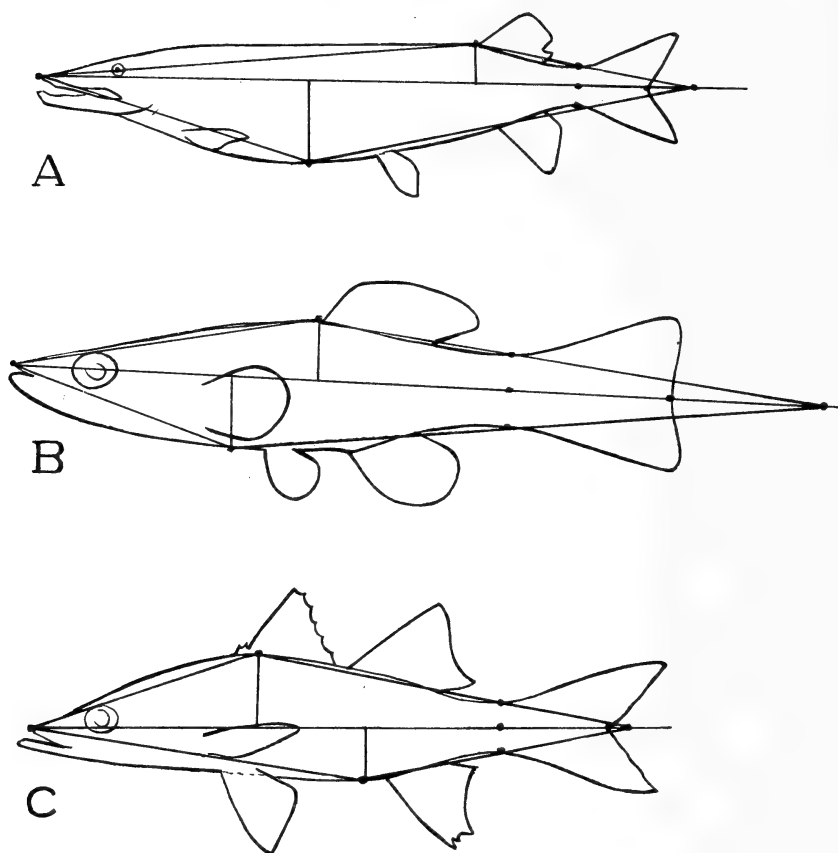


Fig. 122. Fishes with flat dorso-anterior slope and low entering angles. A, Pike (*Lucius masquinongy*); B, Killifish (*Fundulus diaphanus*) ♂; C, Snook (*Oxylabrax undecimalis*). Outlines after Jordan and Evermann.

- (c) mouth large and directed upward, many percomorphs, barracudas; or small and directed upward (pœciliids);
  - (d) snout long, as in sturgeons, gar-pikes, *Trichiurus* etc;
  - (e) ascending processes of premaxillæ very long, as in *Hæmulon*, *Gerres*.
10. Antero-ventral contour, forming the lower border of the entering wedge, nearly always protruding convexly below the corresponding boundary (*PG*) of the quadrilateral, especially in free-swimming fishes with a compressed body and head. On the other hand, the antero-ventral contour is often flat or slightly concave in forms with depressed head, either free-swimming, as in *Pristis* and the pikes, or bottom-feeding, as in the batoids and mullids. A convex border doubtless pushes the water to one side, while a concave lower border would tend to produce a slight suction on the under side of the head, and thus to lower it.
  11. The postero-dorsal contour of the back and the base of the dorsal fin usually correspond rather closely to the postero-dorsal boundary of the quadrilateral, which is a line drawn from the apex through the epipygidion. This is especially true in long-bodied fishes. On the contrary, the dorsal contour is apt to protrude widely above the postero-dorsal boundary in deep bodied fishes that have a combination of a high antero-dorsal (*ad*) and a low postero-dorsal vertical (*pd*) (Fig. 124D).
  12. The postero-ventral contour seldom approaches the corresponding boundary (*GO*) of the quadrilateral as closely as does the postero-dorsal contour; frequently the postero-ventral contour retreats proximad away from the boundary. This "cutaway" effect, which is especially marked in fishes with a deep belly (Figs. 123B, 127), facilitates the backward flow of the water displaced by the ventral part of the body.

#### VARIABLE FACTORS OF BODY-FORM

##### I. *Variable relations of the parts of the quadrilaterals*

1. Proportions of total anterior vertical diameter (*ad* + *av*) to body length<sup>1</sup> (*Pp*) (Fig. 124).
  - (a) Vertical = or < 1/10 body length (Fig. 124A) (hyperdolichosomatic)
  - (b) Vertical > 1/10 to 1/5 inclusive (Fig. 124B) (dolichosomatic)
  - (c) Vertical > 1/5 to 1/3 inclusive (Fig. 124C) (mesosomatic)
  - (d) Vertical > 1/3 (hypsosomatic) (Fig. 124D).
2. Antero-posterior relations of apex to gasterion.
  - (a) Gasterion behind apex, *i. e.*, ventral vertical behind

<sup>1</sup> Prosthion to pygidion.



- dorsal vertical; e. g., *Neomænus apodus*, (Fig. 125A) *Calamus proridens* (Fig. 126D). (gasterion postapical).  
(b) Gasterion immediately below apex, ventral vertical im-

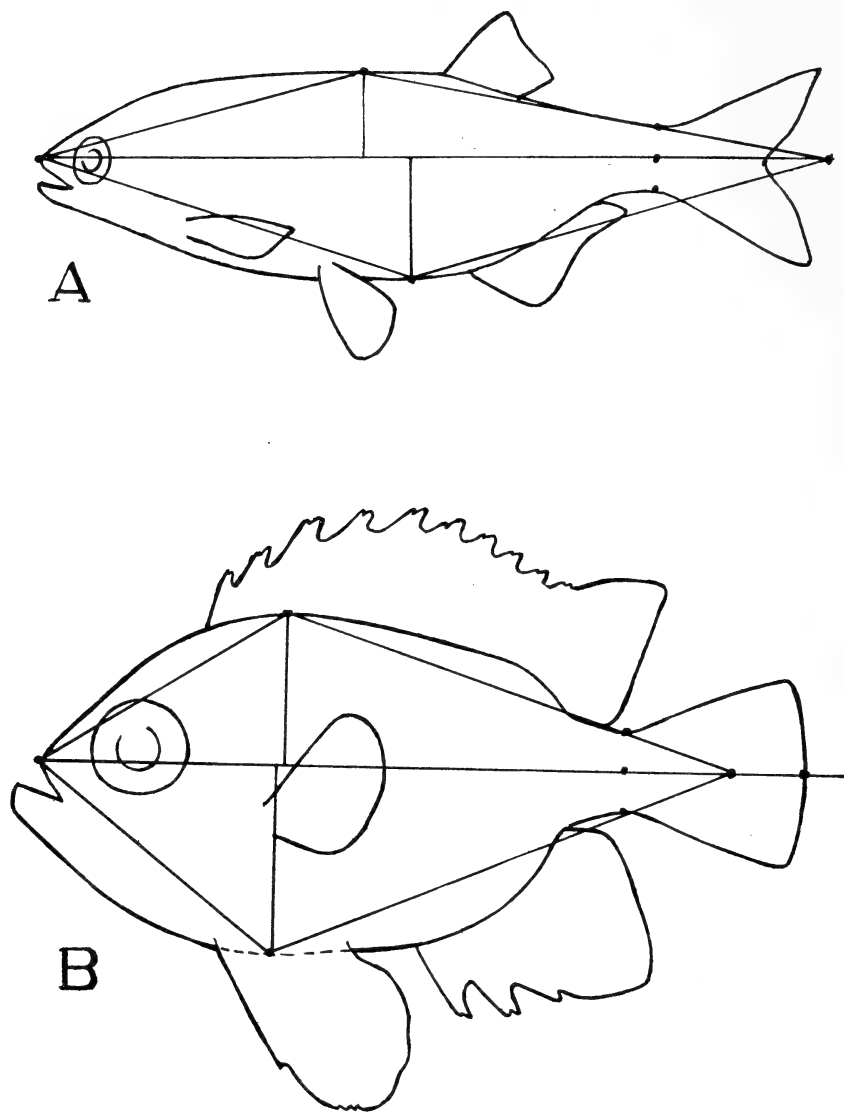


Fig. 123. Cutaway condition of postero-ventral contour. A, *Hiodon tergisus*; B, *Pseudopriacanthus altus*. Outlines after Jordan and Evermann.

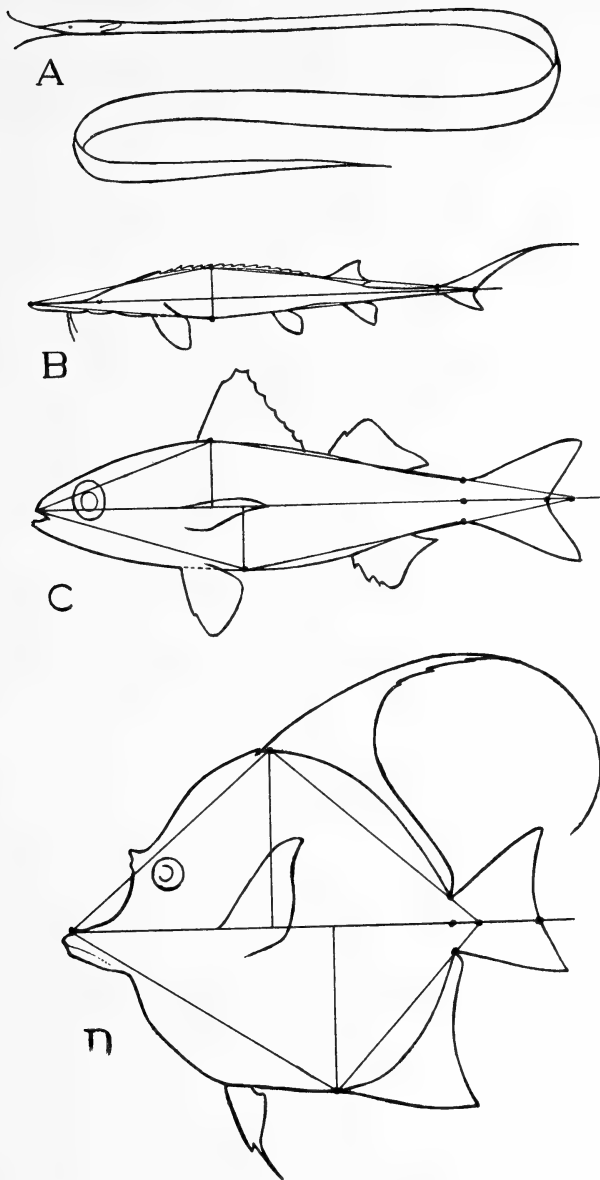


Fig. 124. The four types of body-form based on the ratio of depth to body length (prosthion to pygidion). A, Hyperdolichosomatic (*Labichthys elongatus*); B, Dolichosomatic (*Scaphirhynchus platorhynchus*); C, Mesosomatic (*Xenocys jessiae*); D, Hypsisomatic (*Zanclus cornutus*). Outlines after Jordan and Evermann.

- mediately below dorsal vertical; *e. g.*, many sharks (Fig. 117A), sturgeons (Fig. 124B), protospondyls, isospondyls (Fig. 117B) acanthoptes (Fig. 117C) (gasterion subapical).
- (c) Gasterion in front of apex; *i. e.*, ventral vertical in front of dorsal vertical; *e. g.*, *Tarpon atlanticus*, *Atherinopsis californiensis* (Fig. 125C) (gasterion preapical).

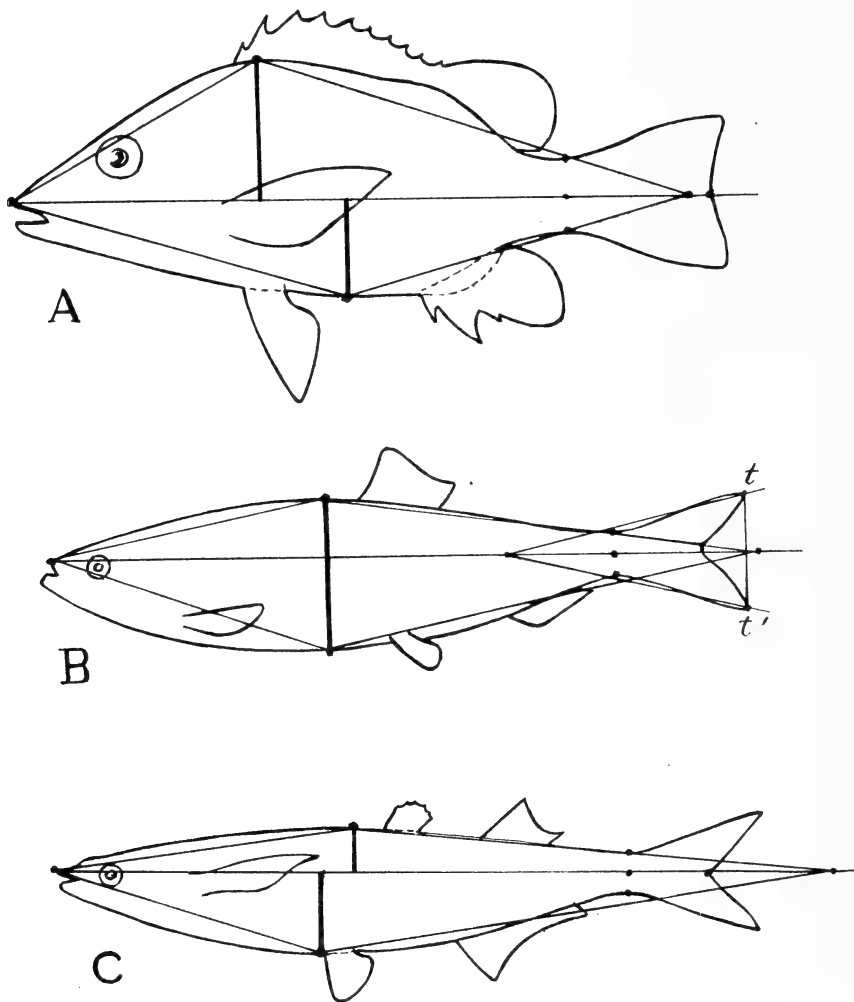


Fig. 125. Varying antero-posterior relations of apex to gasterion. A, Gasterion post-apical (*Neomænis apodus*); B, Gasterion subapical (*Clupea harengus*); C, Gasterion preapical (*Atherinopsis californiensis*). Outlines after Jordan and Evermann.

3. Antero-posterior relations of apex to horizontal.
  - (a) Vertical of apex falling in anterior third of horizontal (apex anterior).
  - (b) Vertical of apex falling in middle third of horizontal (apex median).
  - (c) Vertical of apex falling in posterior third of horizontal (apex posterior).
4. Variable antero-posterior relations of gasterion to horizontal.
  - (a) Vertical of gasterion in anterior third of horizontal (Fig. 121C) (gasterion anterior).
  - (b) Vertical of gasterion in middle third of horizontal (gasterion median).
  - (c) Vertical of gasterion in posterior third of horizontal (gasterion posterior).
5. Dorso-ventral relations of apex to horizontal.
  - (a) Dorsal vertical ( $ad$ ) = or  $< 1/20$  body length (Fig. 126A) (hyperdolichonotic).
  - (b) Dorsal vertical  $> 1/20$  to  $1/10$  inclusive (Fig. 126B) (dolichonotic).
  - (c) Dorsal vertical  $> 1/10$  to  $1/6$  inclusive (Fig. 126C) (mesonotic).
  - (d) Dorsal vertical  $> 1/6$  (hypsinotic) (Fig. 126D).
6. Dorso-ventral relations of gasterion to horizontal.
  - (a) Antero-ventral vertical = or  $< 1/20$  body length (Fig. 126A) (hyperdolichogastric).
  - (b) Antero-ventro vertical  $> 1/20$  to  $1/10$  inclusive (Fig. 126B) (dolichogastric).
  - (c) Antero-ventral vertical  $> 1/10$  to  $1/6$  inclusive (Fig. 126C) (mesogastric).
  - (d) Antero-ventral vertical  $> 1/6$  (Fig. 127) (bathygastric).
7. Proportions of total posterior vertical ( $pd + pv$ ) to maximum body depth ( $ad + av$ ). (Posterior vertical minimum depth of caudal peduncle)
  - (a) Posterior vertical ( $pd + pv$ )  $< 1/4$  anterior vertical ( $ad + av$ ). (Fig. 128B) (leptopygidial).
  - (b) Posterior vertical  $1/4$  to  $< 1/2$  anterior vertical. (nomopygidial).
  - (c) Posterior vertical  $1/2$  or  $> 1/2$  anterior vertical (Fig. 128A). (macropygidial).
8. Antero-posterior relations of opisthion and uranion.
  - (a) Opisthion behind uranion (opisthion posturanic). The normal condition.
  - (b) Opisthion coincides with uranion (opisthion uranic) (Fig. 117C).
  - (c) Opisthion in front of uranion (opisthion preuranic) (Fig. 128B, 127C, 126D, 124D, 123B).

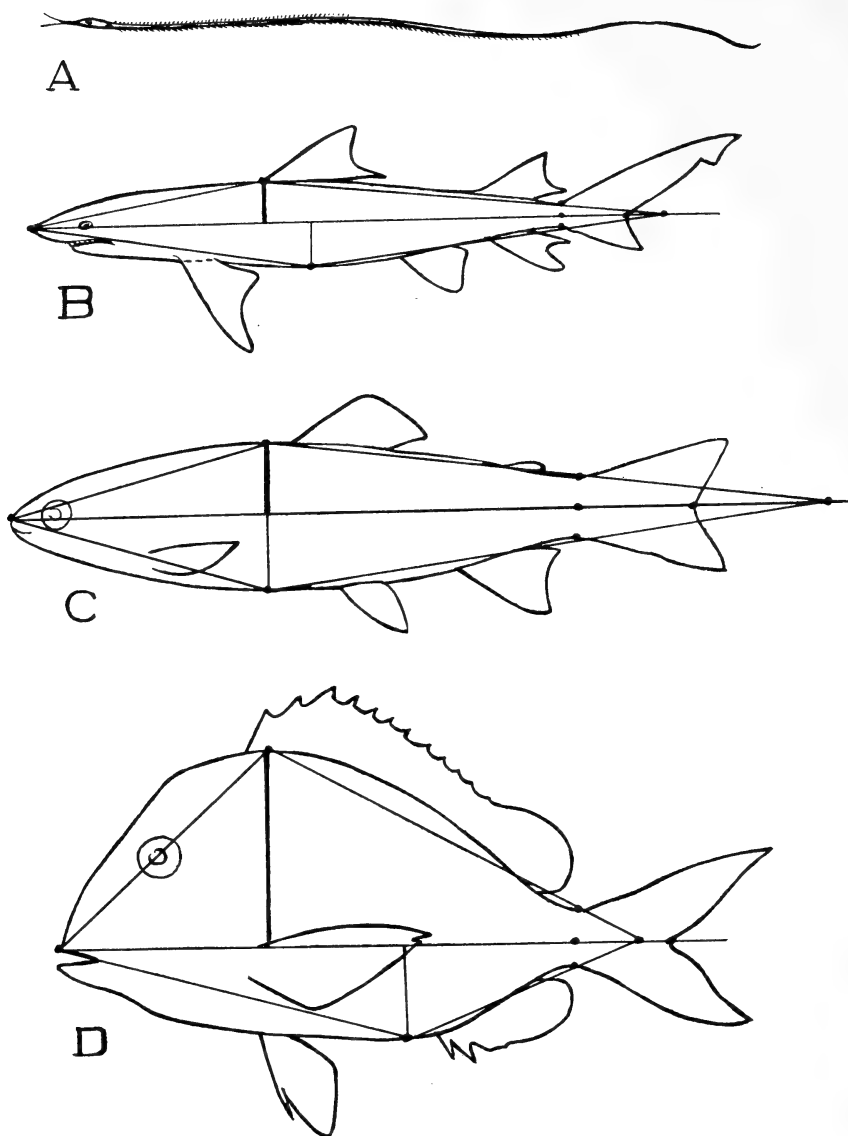


Fig. 126. Varying depth of back. A, Hyperdolichonotic (*Nemichthys avocetta*); B, Dolichonotic (*Hypoprion brevirostris*); C, Mesonotic (*Salmo clarkii stomias*); D, Hypsinotic (*Calamus proridens*). Outlines after Jordan and Evermann.

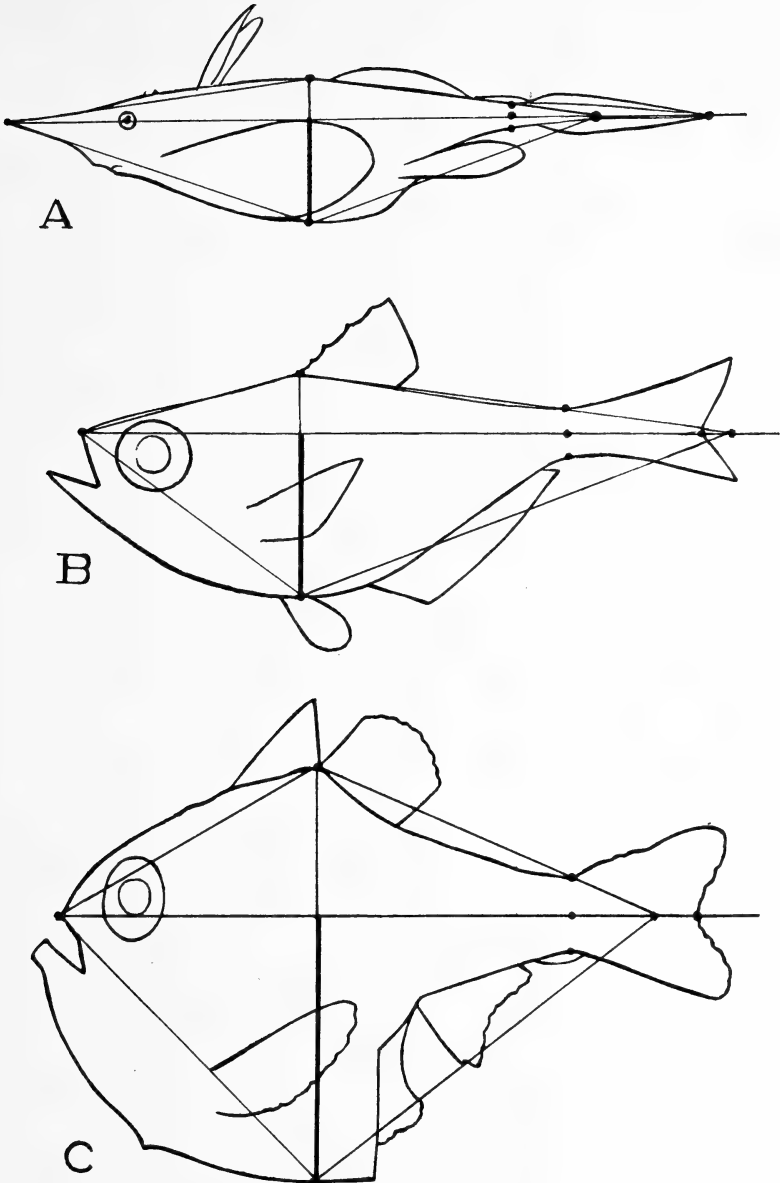


Fig. 127. Bathygastrie forms. A, *Harriotta raleighana*; B, *Pempheris poeyi*; C, *Argyropelecus olfersi*. Outlines after Jordan and Evermann.

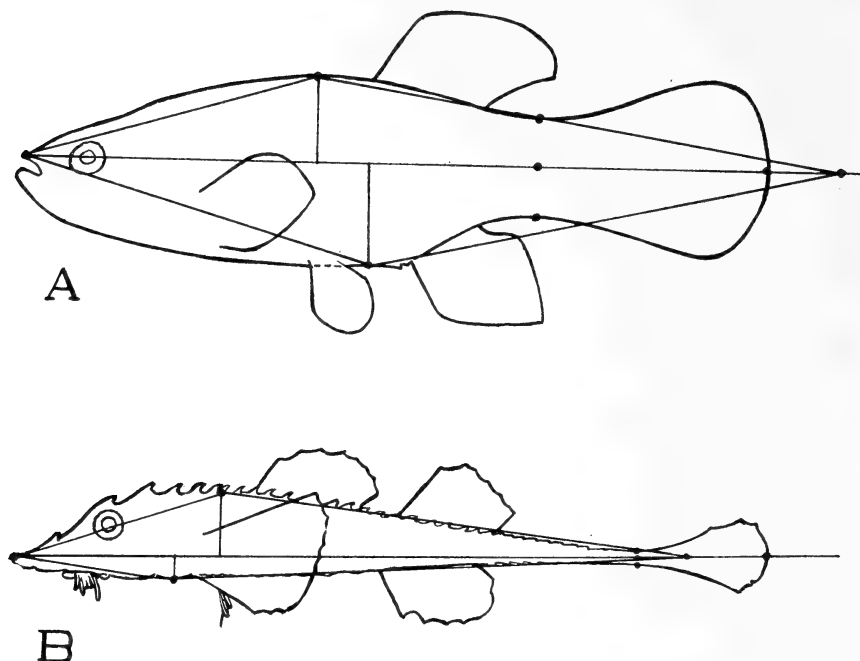


Fig. 128. Macropygidial (A) and leptopygidial (B) forms. A, *Fundulus heteroclitus*; B, *Podothecus veterinus*. Outlines after Jordan and Evermann.

## II. Variable forms and positions of the fins.

1. Relations of maximum spread of caudal fin to body depth ( $ad + av$ ).
  - (a) Maximum spread of tail  $< 1/3$  body depth (microcercal) (Fig. 129D).
  - (b) Maximum spread of tail  $1/3$  to  $3/4$ , inclusive, depth (nomocercal).
  - (c) Maximum spread of tail  $< 3/4$  depth (macrocercal) (Fig. 129A, B, C).
2. Relations of basal length of tail (pygidion to uranion [ $p u$ ]) to maximum spread of tail ( $t t'$ ).
  - (a) Basal length of tail  $> 1/1$  maximum spread (dolichocercal) (Fig. 128B).
  - (b) Basal length of tail  $1/1$  to  $1/2$  inclusive (mesocercal).
  - (c) Basal length of tail  $< 1/2$  spread (brachycercal).
3. Shape of caudal fin.
  - (a) Caudal fin hypocercal (reversed heterocercal) (Fig. 130A)
  - (b) Caudal fin heterocercal (epicercal). Varieties of the heterocercal type are illustrated and named in Figs. 130, 131, 132, and 133.

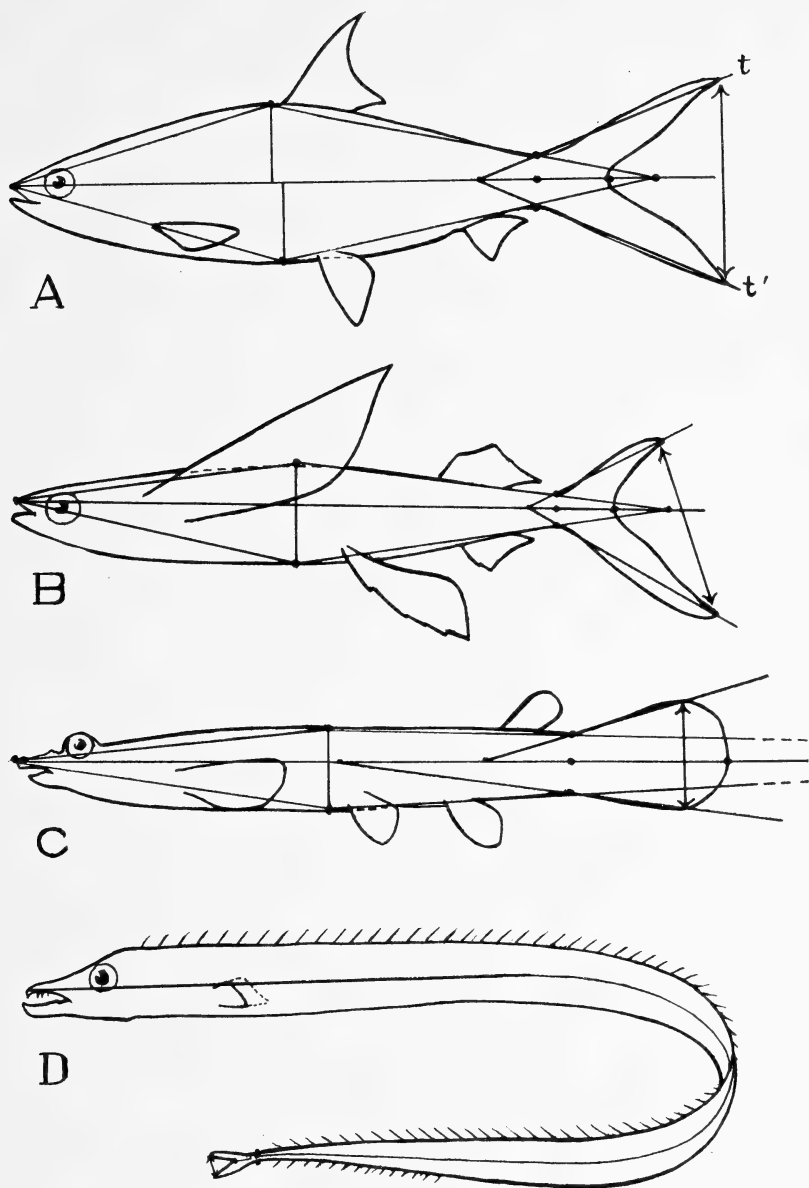


Fig. 129. Macrocercal (A, B, C) and microcercal (D) forms. A, *Chanos chanos*; B, *Cypselus californicus*; C, *Anableps dovi*; D, *Lepidopus caudatus*. Outlines after Jordan and Evermann.



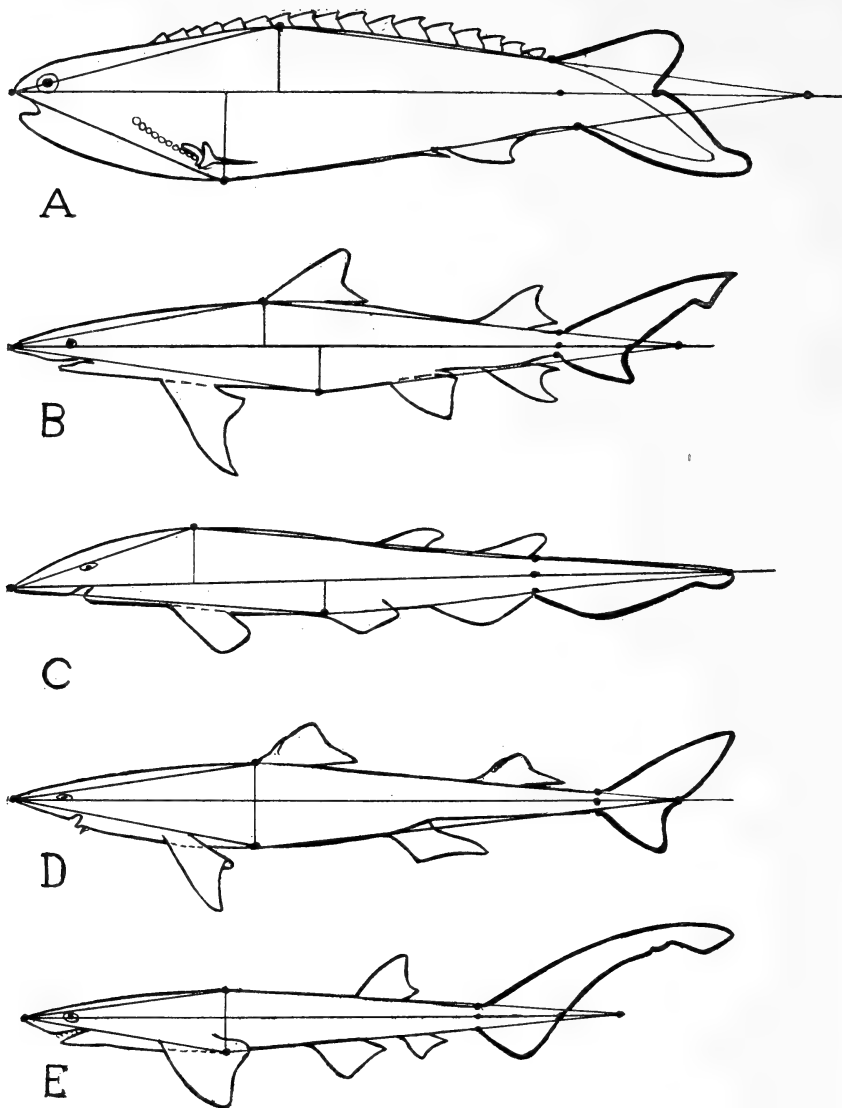


Fig. 130. Hypocercal and heterocercal (epicercal) tails. A, Hypocercal (*Pterolepis nitidus*, Upper Silurian, Norway). After Kiaer; B-I, Heterocercal: B, typical (*Hypoprion brevirostris*); C, horizontal (*Scylliorhinus profundum*); D, asymmetrical (*Squalus acanthias*); E, elongate (*Notorhynchus maculatus*). Outlines after Jordan and Evermann.

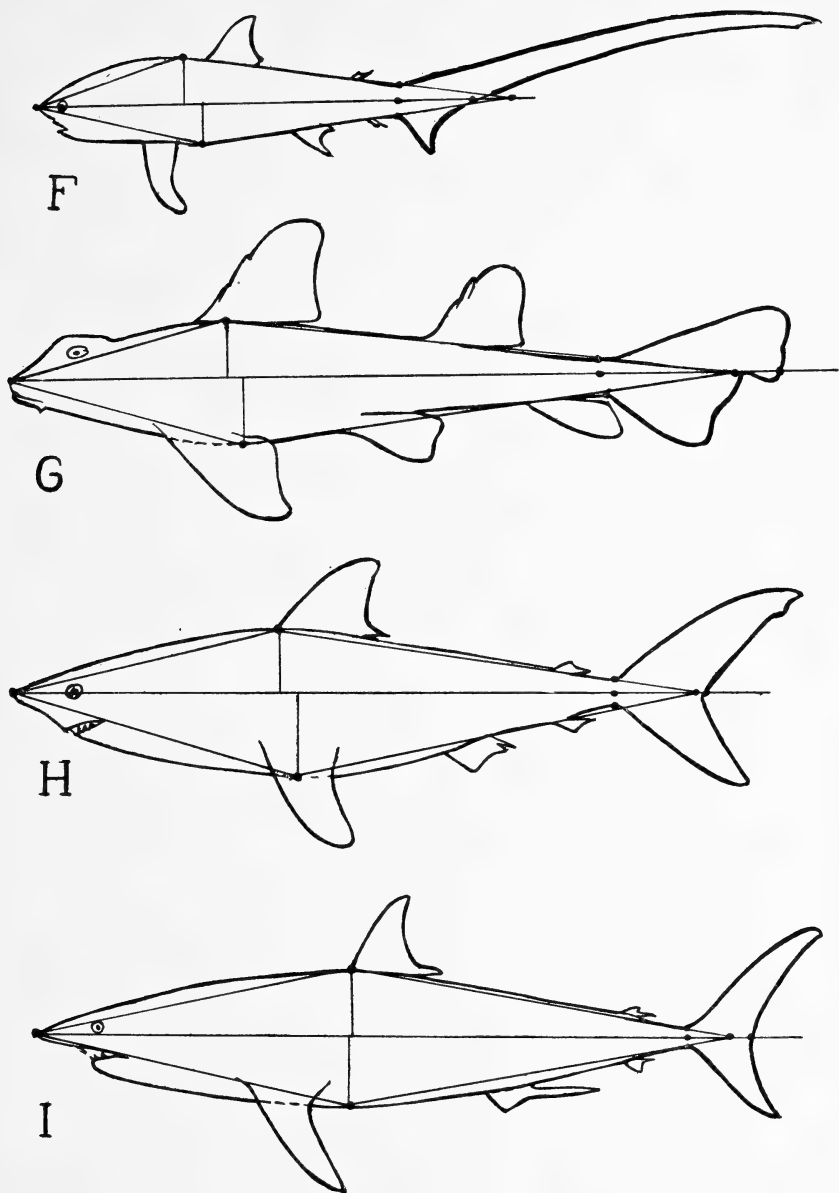


Fig. 131. Heterocercal types continued. F, Perelongate (*Alopias vulpes*); G, robust (*Gyropleurodus francisci*); H, bifurcate (*Lamna cornubica*); I, subcaudate (*Isurus dekayi*). Outlines after Jordan and Evermann.

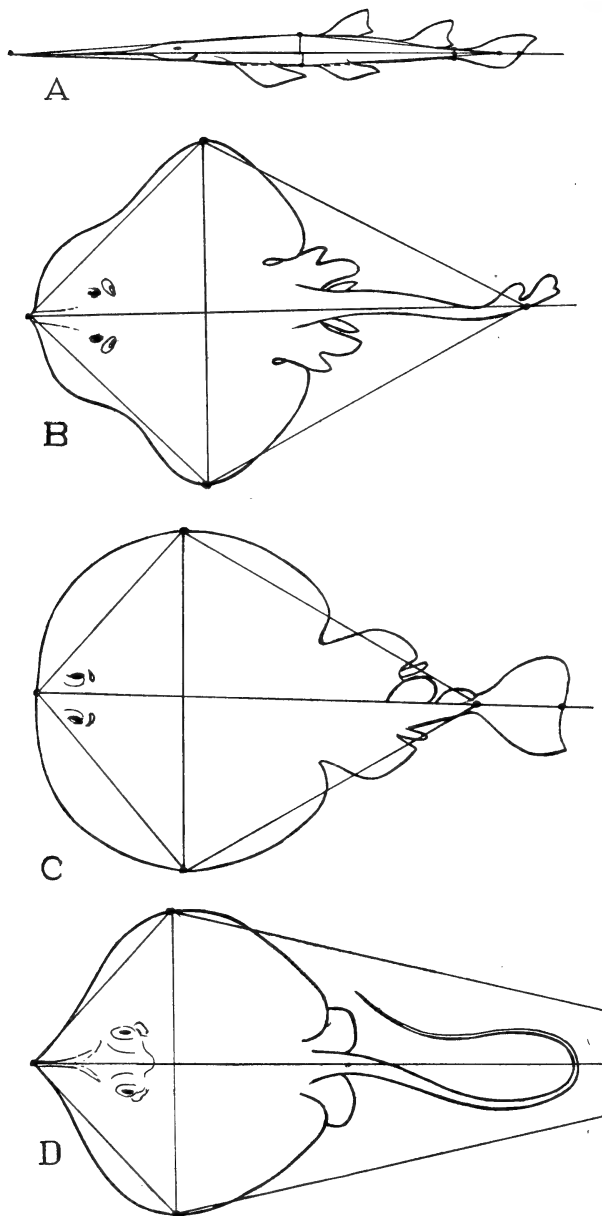


Fig. 132. Modified heterocercal types. A, Scalene (*Pristis pectinatus*); B, bipinnate (*Raja ocellata*); C, truncate (*Tetranarce occidentalis*); D, filiform (*Dasyatis sabina*). Outlines after Jordan and Evermann.

- (c) Caudal fin tristichopterous (Fig. 133D).
- (d) Caudal fin diphyccercal (Fig. 133C).
- (e) Caudal fin hemiheterocercal: ( $\alpha$ ) lunate, ( $\beta$ ) bifurcate, ( $\gamma$ ) crescentic, ( $\delta$ ) truncate, ( $\epsilon$ ) convex, ( $\zeta$ ) spatulate.

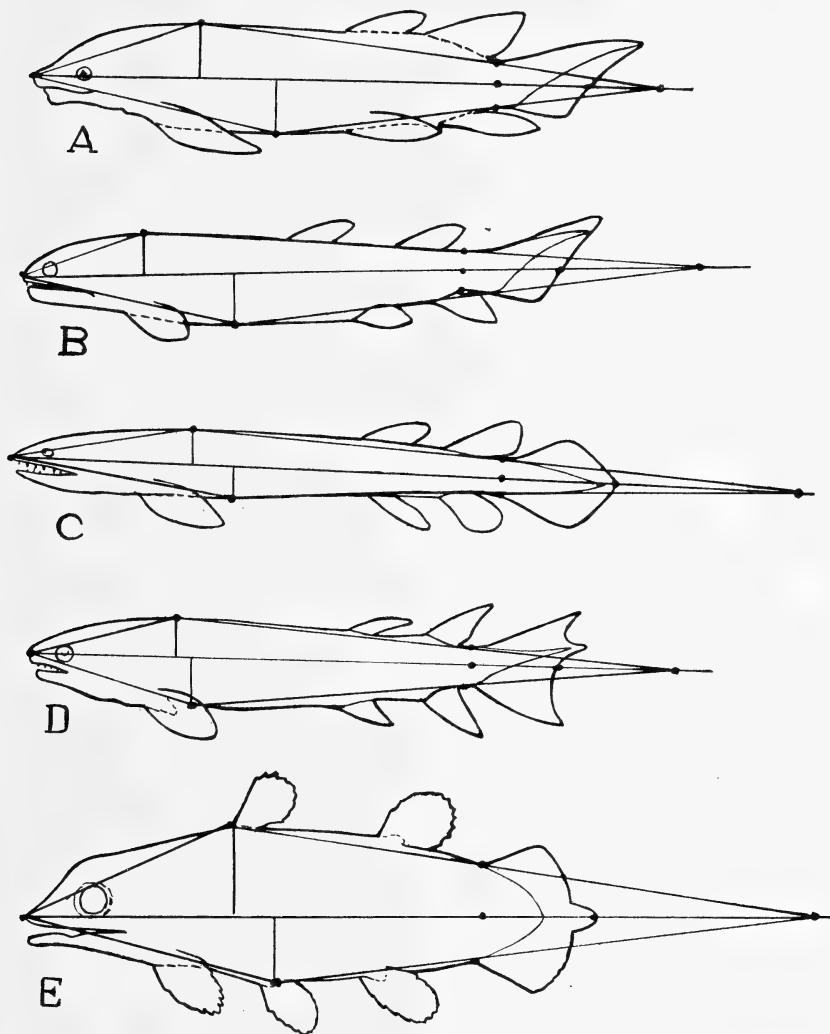


Fig. 133. Modified heterocercal types (continued). A, Acute (*Dipterus valenciennesii*); B, acute (*Osteolepis macrolepidotus*); C, diphyccercal (*Glyptopomus kinnairdii*); D, tristichopterous concave (*Tristichopterus alatus*); E, tristichopterous convex (*Undina gulo*). All from Goodrich after Traquair.

- (f) Caudal fin homocercal. The varieties of the homocercal type are shown in Figs. 134, 135.
- (g) Caudal fin gephyrocercal. The varieties of the gephyrocercal type are shown in Fig. 136.

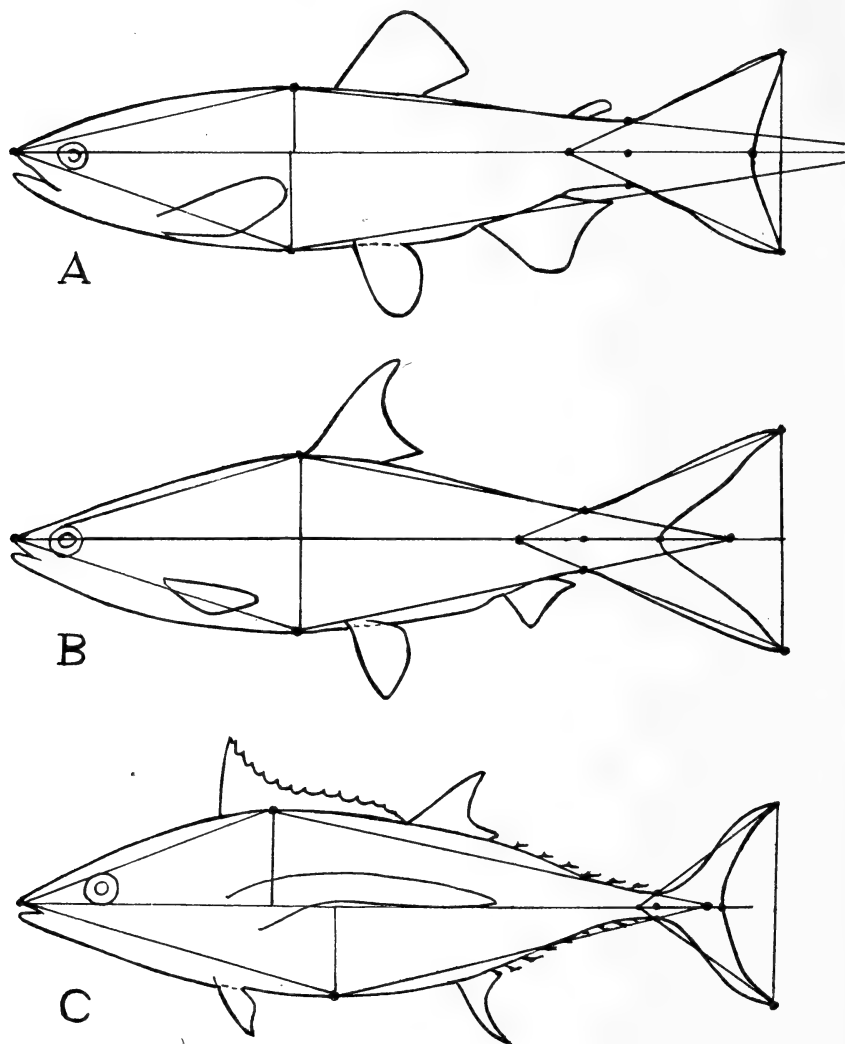


Fig. 134. Homocercal types. A, Lunate (*Oncorhynchus nerka*); B, bifurcate (*Chanos chanos*); C, crescentic (*Germo alalunga*). Outlines after Jordan and Evermann.

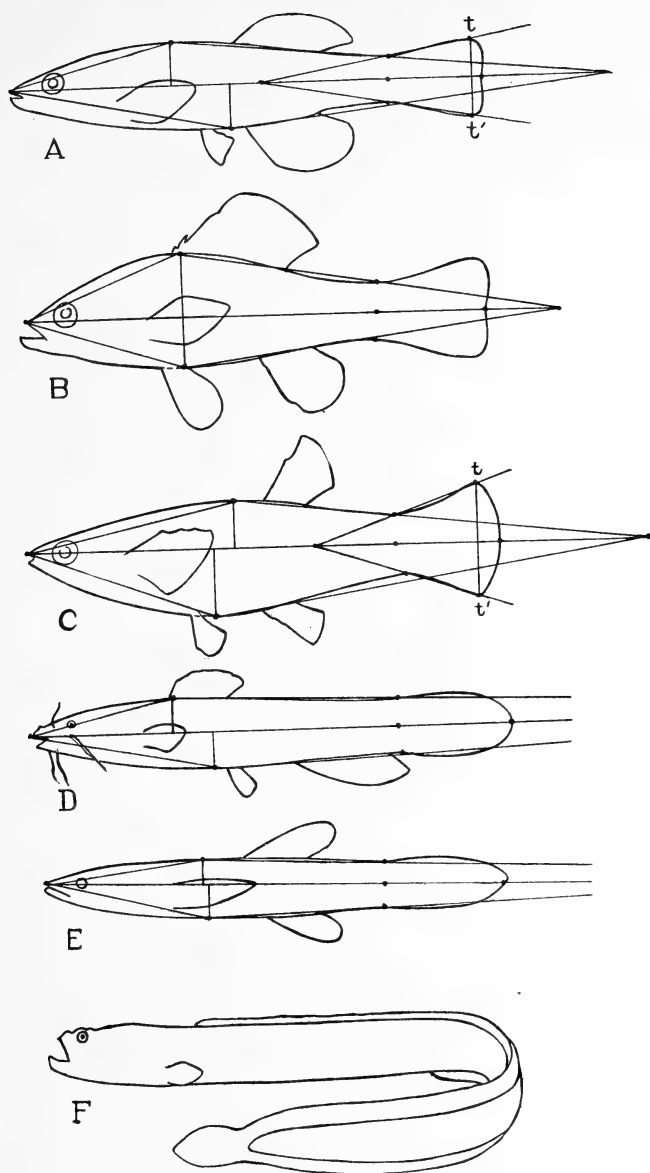


Fig. 135. Homocercal types (continued). A, Truncate (*Fundulus zebrinus*); B, truncate emarginate (*Aphredoderus sayanus*); C, convex (*Pecilia presidionis*); D, spatulate convex (*Schilbeodes exilis*); E, spatulate pointed (*Chologaster cornutus*); F, gephyrocercal incipient (*Cryptacanthodes maculatus*). Outlines after Jordan and Evermann.

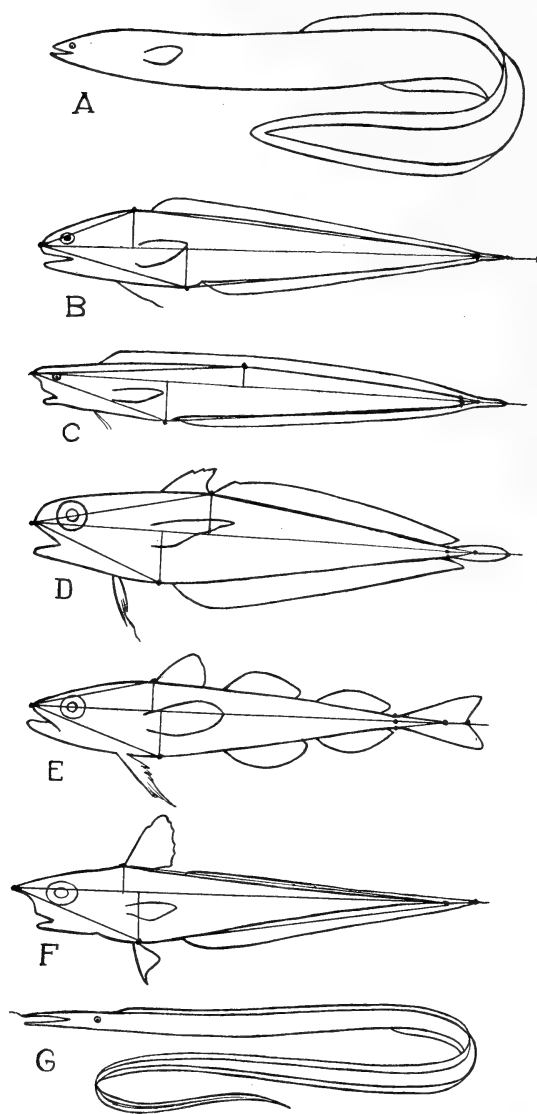


Fig. 136. Geophyrocercal types. A, Typical (*Anguilla chrysypa*); B, pointed or diphy-cercoid (*Neobythites marginatus*); C, pseudomocercal incipient (*Barathrodemus manatinus*); D, pseudomocercal spatulate (*Physiculus fulvus*); E, pseudomocercal lunate (*Porogadus saida*); F, geophyrocercal hypural (*Cælorhynchus carminatus*); G, geophyrocercal filiform (*Veneficia procera*). Outlines after Jordan and Evermann.

4. Antero-posterior relations of first dorsal fin to horizontal.
  - (a) Middle of base of first dorsal falls in first quarter of horizontal (prosthion to opisthion) (Fig. 137A).
  - (b) Middle of base of first dorsal falls in second quarter of horizontal (Fig. 137B).
  - (c) Middle of base of first dorsal falls in third quarter of horizontal (Fig. 137C).
  - (d) Middle of base of first dorsal falls in fourth quarter of horizontal (Fig. 137D).
5. Extent of first dorsal fin base to body length.
  - (a) Length of dorsal fin base  $< 1/10$  body length (first dorsal brevibasic) (Fig. 138A).
  - (b) Length of dorsal fin base  $1/10$  to  $1/4$  inclusive (first dorsal medibasic) (Fig. 138B).
  - (c) Length of dorsal fin base  $> 1/4$  to  $1/2$  body length (first dorsal longibasic) (Fig. 138C).
  - (d) Length of dorsal fin base  $> 1/2$  body length (first dorsal perlongibasic) (Fig. 138D).
6. Height of dorsal fin from its summit to its base measured along the rays (excluding filaments), to body depth.
  - (a) Length  $< 1/3$  body depth (first dorsal breviradial) (Fig. 139A).
  - (b) Length  $1/3$  to  $3/4$  inclusive (first dorsal mediradial) (Fig. 139B).
  - (c) Length  $> 3/4$  body depth (first dorsal longiradial) (Fig. 139C).
7. Shape of first dorsal fin.
  - (a) Postero-superior border concave (Fig. 137B, 134B).
  - (b) Postero-superior border flat (Fig. 135F, 136B).
  - (c) Postero-superior border convex (Fig. 135B) or spatulate (Fig. 135C).
8. Relations of second dorsal to first.
  - (a) Completely separated from first dorsal (dorsals separate) (Fig. 138A, B).
  - (b) Separated from it by a more or less deep notch (dorsals notched) (Fig. 138C, D).
  - (c) Continuous with first dorsal (dorsals continuous) (Fig. 139B).
9. Extent of second dorsal fin-base<sup>1</sup> to body length.
  - (a) Length of base  $< 1/12$  body length (second dorsal per-brevibasic) (Fig. 140A).
  - (b) Length of base  $1/12$  to  $< 1/7$  body length (second dorsal brevibasic) (Fig. 140B).
  - (c) Length of base  $1/7$  to  $< 1/3$  body length (second dorsal medibasic) (Fig. 140C).

<sup>1</sup> Adipose fins excluded.



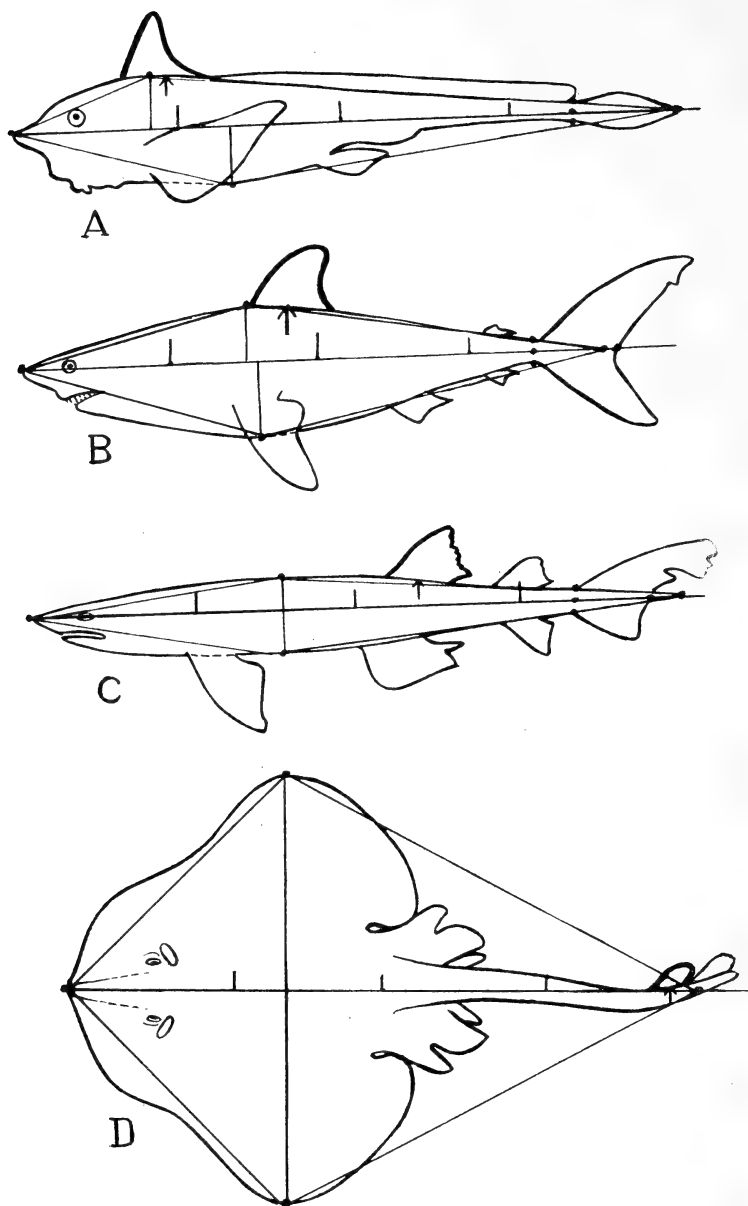


Fig. 137. Varying anteroposterior positions of first dorsal fin. A, Middle of base of first dorsal in first quarter of horizontal (*Chimæra affinis*); B, in second quarter (*Lamna cornubica*); C, in third quarter (*Catulus uter*); D, in fourth quarter (*Raja ocellata*). Outlines after Jordan and Evermann.

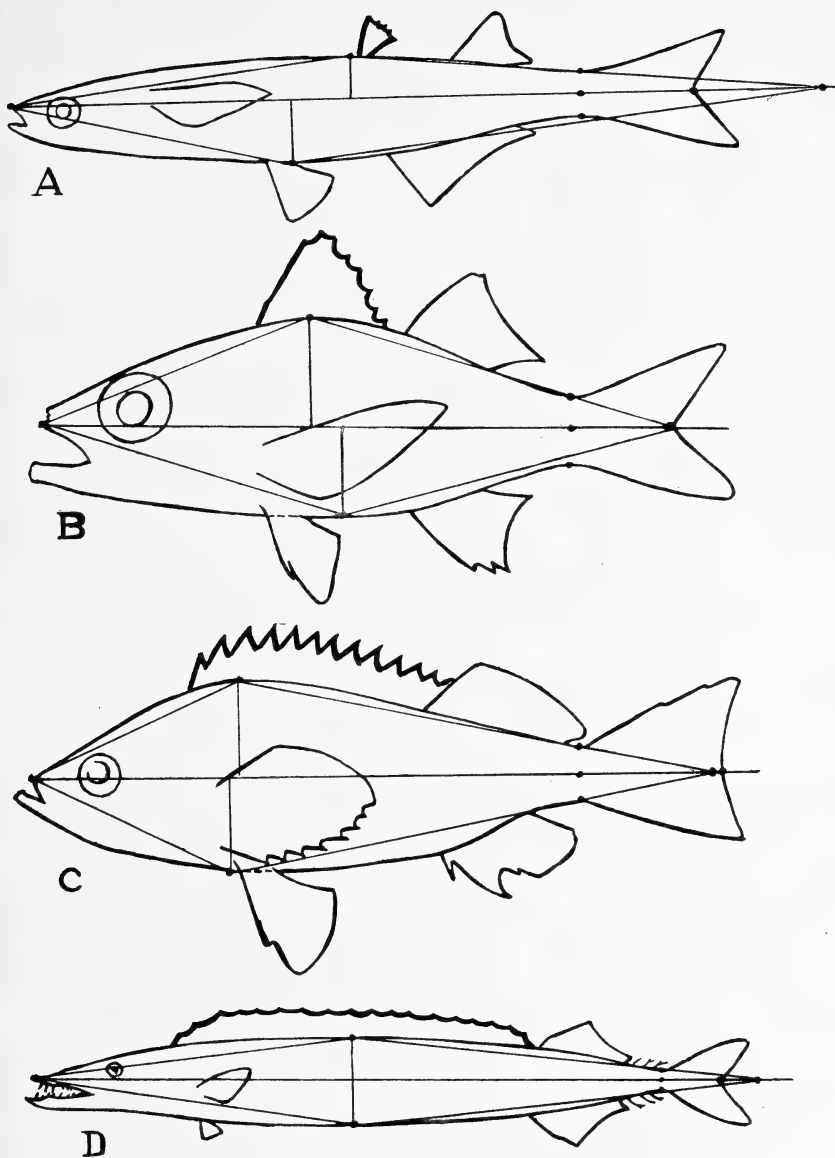


Fig. 138. Extent of first dorsal fin base to body length (prosthion to pygidion). A, First dorsal brevbasic (*Kirtlandia vagrans*); B, medibasic (*Verilus sordidus*); C, longibasic (*Sebastes hopkinsi*); D, perlongibasic (*Escolar violaceus*). Outlines after Jordan and Evermann.

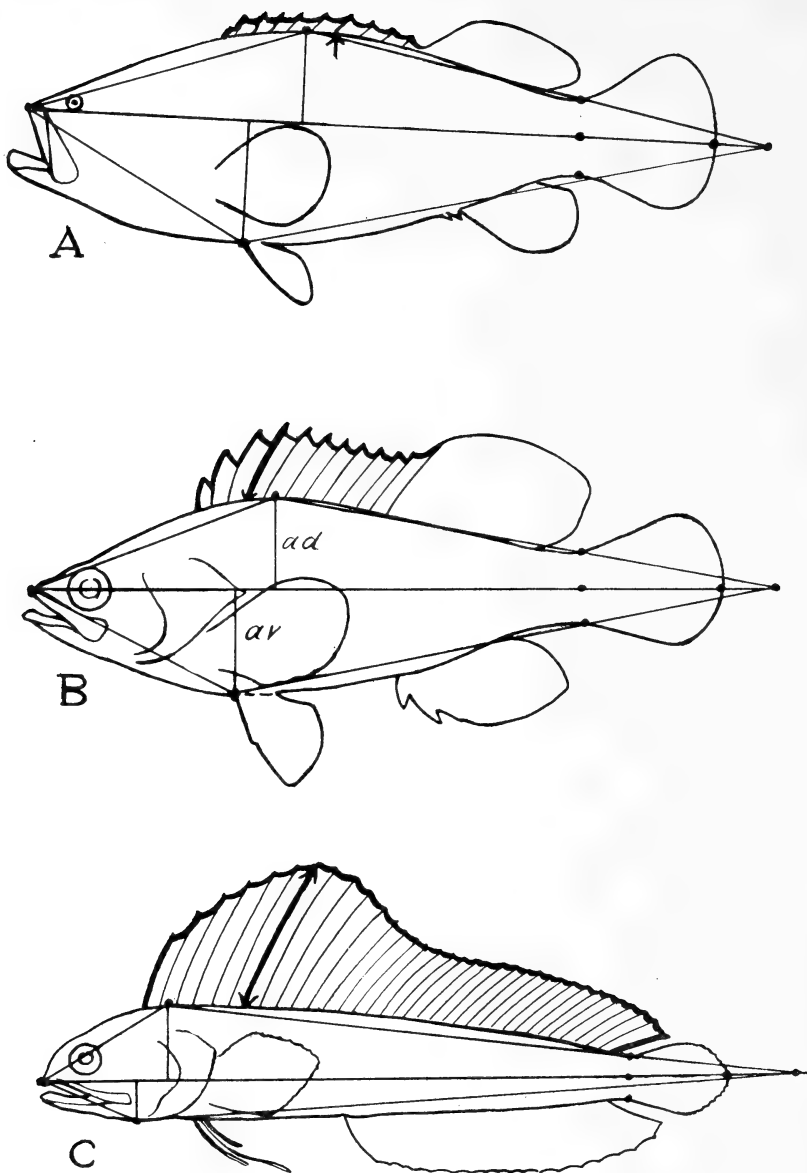


Fig. 139. Height of first dorsal fin to body depth ( $ad + av$ ). A, first dorsal brev-radial (*Promicrops guttatus*); B, mediradial (*Alphestes afer*); C, longiradial (*Emblemaria atlantica*). Outlines after Jordan and Evermann.

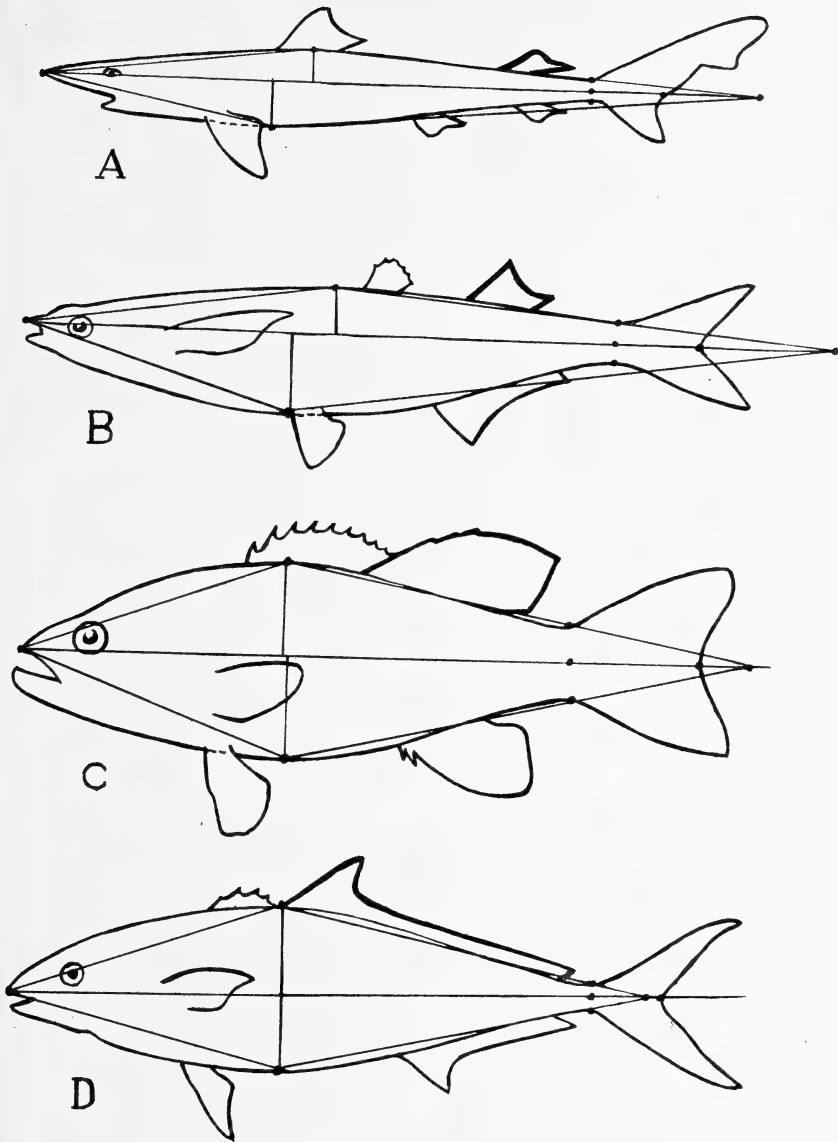


Fig. 140. Extent of second dorsal fin base to body length. A, Second dorsal perbrevisbasic (*Galeorhinus zygopterus*); B, brevibasic (*Atherinopsis californiensis*); C, medibasic (*Micropodus dolomieu*); D, longibasic (*Seriola dorsalis*). Outlines after Jordan and Evermann.

- (d) Length of base  $1/3$  to  $1/2$  or  $> 1/2$  body length (second dorsal longibasic) (Fig. 140D).
- 10. Height of second dorsal to body depth.
  - (a) Longest ray of second dorsal  $< 1/3$  body depth (second dorsal breviral) (Fig. 137B).
  - (b) Longest ray of second dorsal  $1/3$  to  $1/2$  inclusive body depth (second dorsal mediradial) (Fig. 119C).
  - (c) Longest ray of second dorsal  $> 1/2$  to  $1/1$  body depth (second dorsal longiradial) (Fig. 122C).
  - (d) Longest ray of second dorsal  $> 1/1$  body depth (second dorsal perlongiradial) (Fig. 142C).
- 11. Shape of second dorsal fin.
  - (a) Postero-superior border convex or spatulate (Fig. 141B, 129C).
  - (b) Postero-superior border flat (Fig. 118B).
  - (c) Postero-superior border concave (Figs. 140B, 125B, 126B).
  - (d) Postero-superior border produced into process or filament (*Tarpon atlanticus*, and Fig. 130D).
  - (e) Posterior part fragmented into finlets (Figs. 134C, 138D).
- 12. Position of anal fin in relation to dorsal or posterior dorsal fin.
  - (a) Middle of base of anal behind middle of base of dorsal (anal post-dorsal) (Fig. 141A).
  - (b) Middle of base of anal beneath middle of base of dorsal (anal subdorsal) (Fig. 141B, 142).
  - (c) Middle of base of anal in front of middle of base of dorsal (anal predorsal) (Fig. 141C).
- 13. Development of spinous portion of anal fin.
  - (a) Spinous portion strongly developed (Fig. 125A).
  - (b) Spinous portion intermediate (Fig. 141B).
  - (c) Spinous portion weak or absent (Fig. 140C).
- 14. Extent of anal fin base.
  - (a) Length anal fin base  $< 1/10$  body length (anal brevibasic) (Fig. 143A).
  - (b) Length anal fin base  $1/10$  to  $1/3$  body length inclusive (anal medibasic) (Fig. 143B).
  - (c) Length anal fin base  $> 1/3$  to  $1/2$  body length inclusive (anal longibasic) (Fig. 143C).
  - (d) Length anal fin base  $> 1/2$  body length (anal perlongibasic) (Fig. 143D).
- 15. Depth of anal fin.
  - (a) Longest ray  $< 1/3$  body depth (anal breviral) (Fig. 144A).
  - (b) Longest ray  $1/3$  to  $1/2$  body depth (anal mediradial) (Fig. 144B).
  - (c) Longest ray  $> 1/2$  to  $1/1$  body depth (anal longiradial) (Fig. 144C).

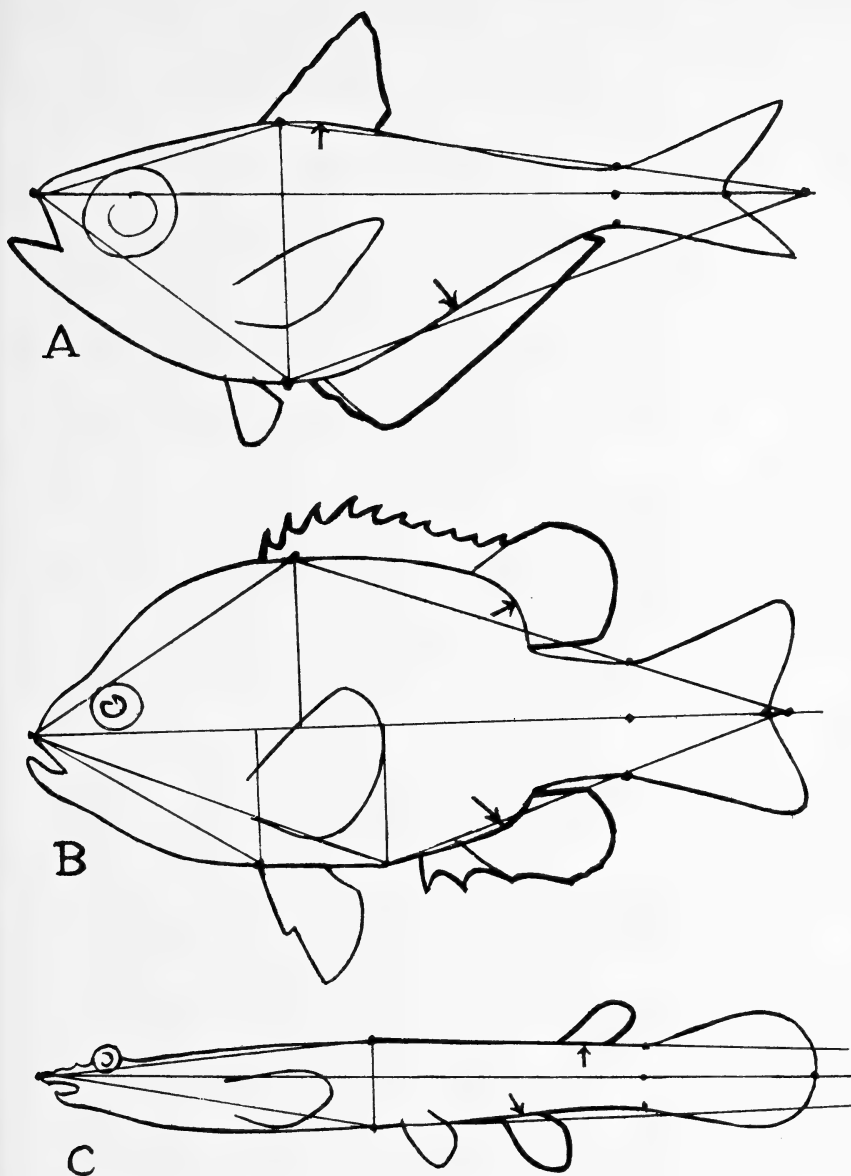


Fig. 141. Varying anteroposterior relations of dorsal and anal fins. A, Anal post-dorsalic (*Pempheris mulleri*); B, sudborsalic (*Lepomis auritus*); C, predorsalic (*Anableps dovi*). Outlines after Jordan and Evermann.

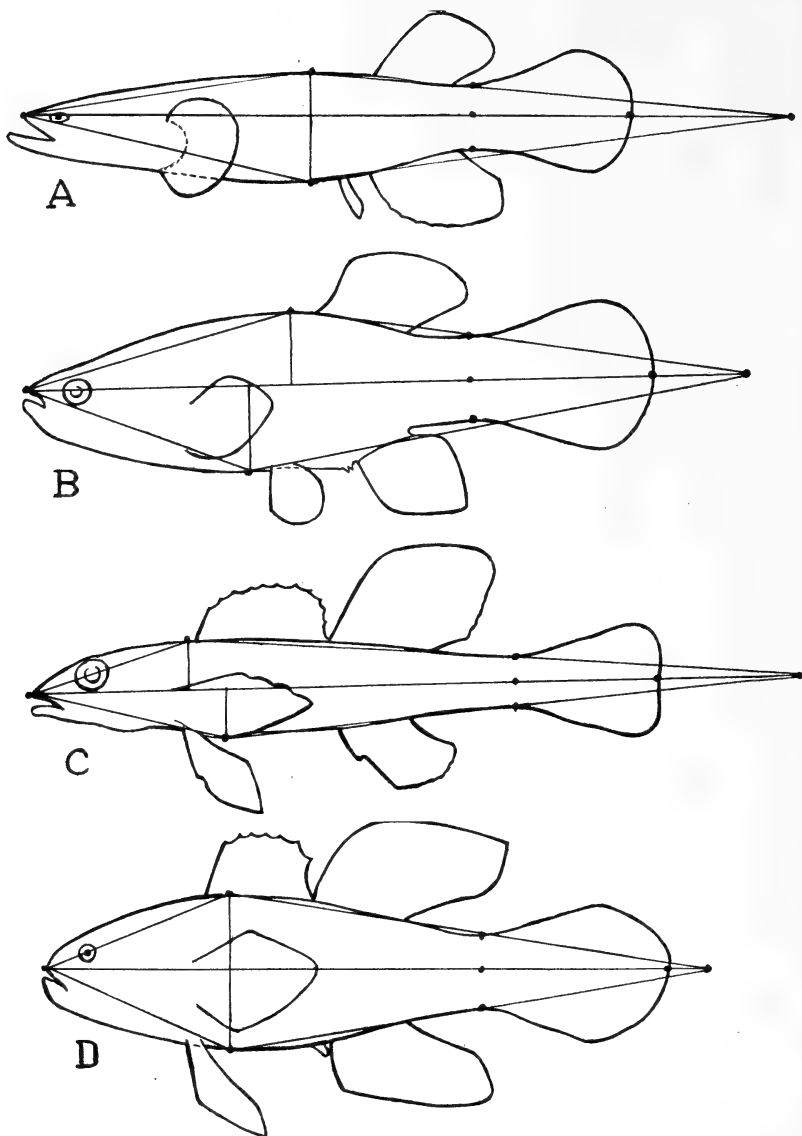


Fig. 142. Sagittate arrangement of large dorsal and anal fins associated with macro-pygidial macrocercal convex homocercal tails and (usually) with low foreheads. Quick darting forms. A, *Dallia pectoralis*; B, *Fundulus heteroclitus*; C, *Etheostoma cinereum*; D, *Dormitator maculatus*. Outlines after Jordan and Evermann.

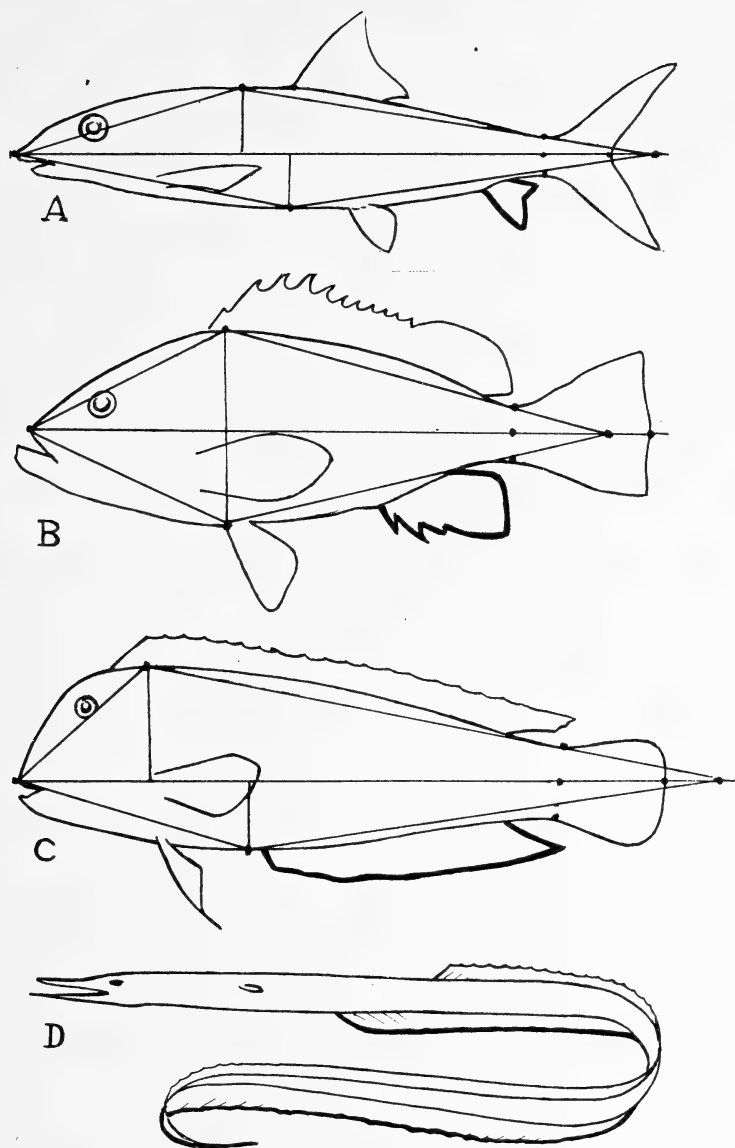


Fig. 143. Varying lengths of anal fin base to body length (Pp). A, Anal brevibasic (*Albula vulpes*); B, medibasic (*Epinephalus drummond-hayi*); C, longibasic (*Xyrichtys psittacus*); D, perlongibasic (*Serrivomer beanii*). Outlines after Jordan and Evermann.



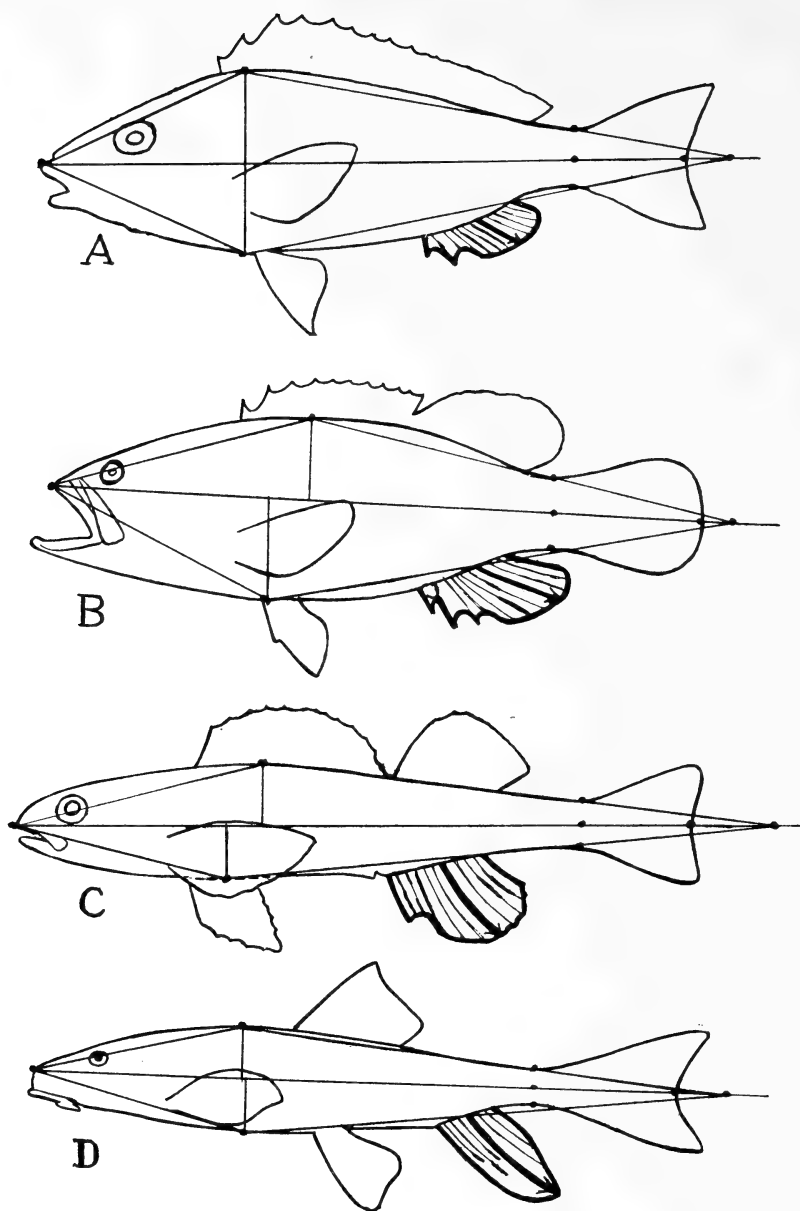


Fig. 144. Varying depth of anal fin to body depth (ad + av). A, Anal breviradial (*Orthopristis reddingi*); B, mediradial (*Epinephalus striatus*); C, longiradial (*Hidropterus evides*); D, perlongiradial (*Catostomus latipinnis*). Outlines after Jordan and Evermann.

- (d) Longest ray  $> 1/1$  body depth (anal perlongiradial) (Fig. 144D).
- 16. Form of anal fin.
  - (a) Postero-inferior border concave (Fig. 145C).
  - (b) Postero-inferior border flat (Fig. 145A).
  - (c) Postero-inferior border convex or spatulate (Fig. 144B).
  - (d) Postero-inferior border pointed (Fig. 144D).
  - (e) Postero-inferior border produced into process (Fig. 126B).
  - (f) Antero-inferior border produced into process (Fig. 119C).
- 17. Position of ventral fins, beneath first, second or third quarter of horizontal.
- 18. Extent of ventral fin-spread to body length.
  - (a) Ventral fin spread  $< 1/10$  body length (pelvics parviareal).
  - (b) Ventral fin spread  $1/10$  to  $1/6$  body length inclusive (pelvics mediareal).
  - (c) Ventral fin spread  $> 1/6$  (pelvics magniareal).
- 19. Length, or proximo-distal diameter, of ventral fin.
  - (a) Ventral fins (longest ray)  $< 1/10$  body length (ventrals breviradial) (Fig. 145A).
  - (b) Ventral fins (longest ray)  $1/10$  to  $1/5$  body length (ventrals mediradial) (Fig. 145B).
  - (c) Ventral fins (longest ray)  $> 1/5$  body length (ventrals longiradial) (Fig. 145C).
- 20. Shape of ventral fin.
  - (a) Postero-external border concave (Fig. 126B).
  - (b) Postero-external border flat (Fig. 122C).
  - (c) Postero-external border convex (Fig. 122B) or spatulate (Fig. 122A).
  - (d) Postero-external border pointed in middle.
  - (e) Anterior border produced into point or into filament (Fig. 124D).
  - (f) Distal border divided into separate rays (Fig. 121C).
  - (g) Ventral fin of "archipterygial" or mesorhachic type ( $\alpha$ ) elongate (Fig. 133C) ( $\beta$ ) abbreviate (Fig. 133E).
- 21. Position of pectoral to horizontal.
  - (a) Dorsal axillary border below horizontal (pectorals inferior) (Fig. 146A).
  - (b) Dorsal axillary border at horizontal (pectorals median) (Fig. 146B).
  - (c) Dorsal axillary border above horizontal (pectorals superior) (Fig. 146C).
- 22. Size of pectoral fin-spread to maximum body depth.
  - (a) Pectoral fin-spread  $< 1/3$  body depth (pectoral parviareal).
  - (b) Pectoral fin-spread  $1/3$  to  $1/2$  body depth (pectoral mediareal).
  - (c) Pectoral fin-spread  $> 1/2$  body depth (pectoral latiareal).

## 23. Length of pectorals to body length.

- (a) Longest ray  $< 1/6$  body length (pectorals breviradial) (Fig. 147A).
- (b) Longest ray  $1/6$  to  $1/3$  body length inclusive (pectorals mediradial) (Fig. 147B).
- (c) Longest ray  $> 1/3$  to  $1/2$  body length inclusive (pectorals longiradial) (Fig. 147C).

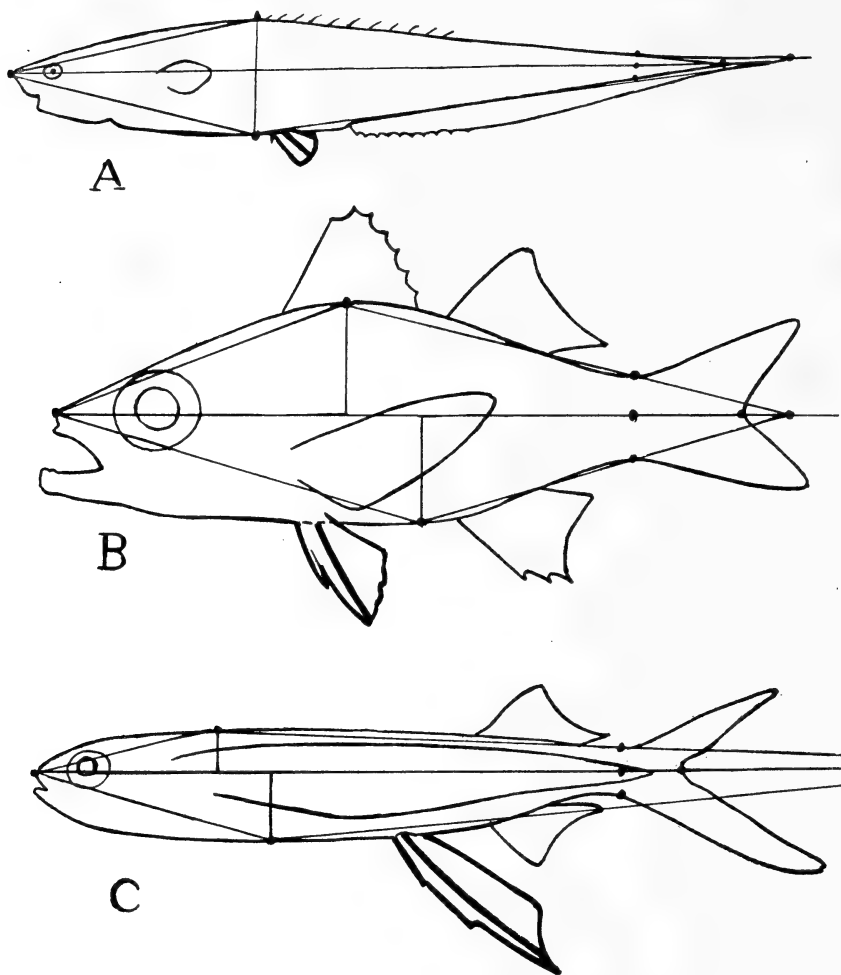


Fig. 145. Varying length of ventrals. A, Ventrals breviradial (*Notacanthus analis*); B, mediradial (*Verilus sordidus*); C, longiradial (*Exonautes rondeletii*). Outlines after Jordan and Evermann.

- (d) Longest ray  $> 1/2$  body length (pectorals perlongiradial) (Fig. 147D).
24. Form of pectorals.
- (a) Pectorals concave (Fig. 130B) or truncate (Fig. 130C).
  - (b) Pectorals spatulate or rounded (Fig. 147A, Fig. 123B).
  - (c) Pectorals intermediate to pointed (Fig. 147B).
  - (d) Pectorals falcate (Fig. 147C).

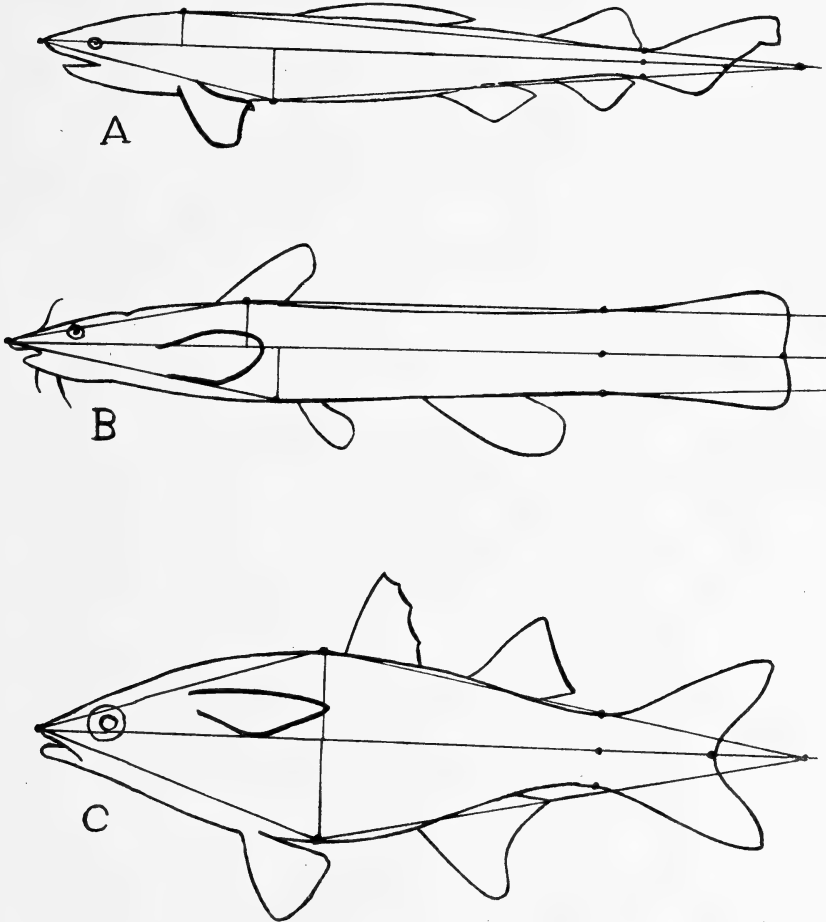


Fig. 146. Varying relations of the pectoral fins to the horizontal. A, Pectorals inferior (*Pseudotriakis microdon*); B, median (*Schilbeodes insignis*); C, superior (*Chænomugil proboscideus*). Outlines after Jordan and Evermann.

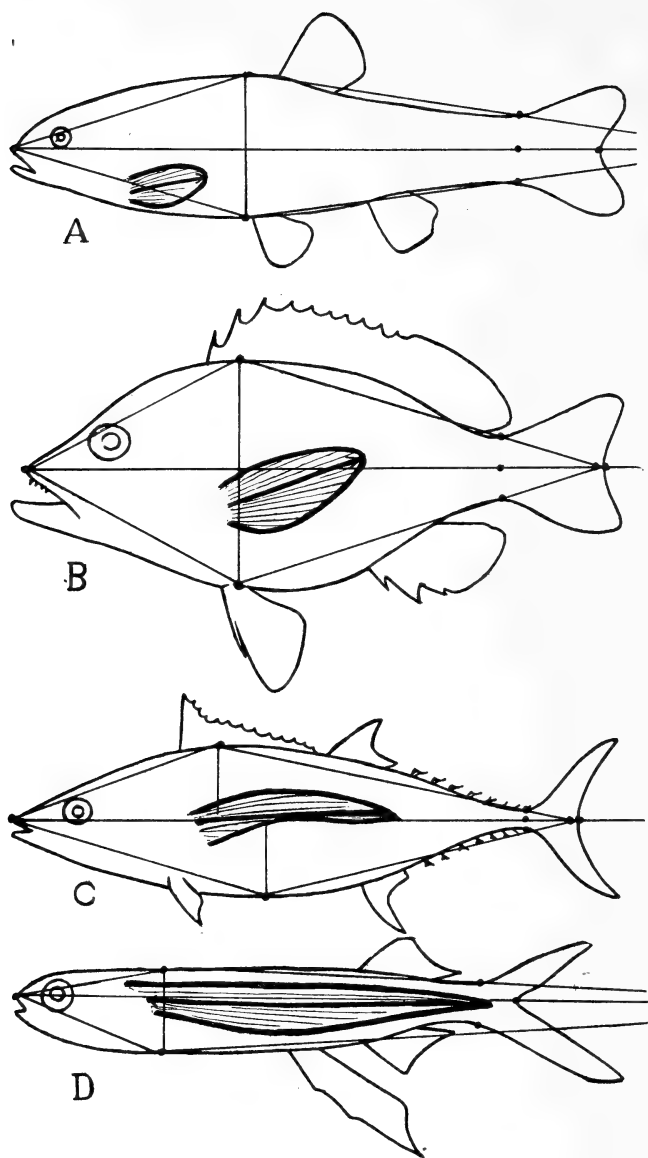


Fig. 147. Varying length of pectorals to body length (Pp). A, Pectorals breviral (Notropis aztecus); B, mediradial (Hypoplectrus unicolor nigricans); C, longiradial (Gerrhonotus alatalunga); D, perlongiradial (Exocoetis rondeletii). Outlines after Jordan and Evermann.

- (e) Pectorals "archipterygial" or mesorhachic (Fig. 133).
  - ( $\alpha$ ) elongate (Fig. 133A).
  - ( $\beta$ ) abbreviate (Fig. 133E).
- (f) Pectorals batoid (Fig. 132).
- (g) Pectorals more or less subdivided distally into long rays or filaments (Polynemidæ, Triglidæ, *Bathypterois*).

### III. *Variable proportions of the head and its parts.*

1. Proportion of head length to body length.
  - (a) Head length  $< 1/5$  body length (microcephalic) (Fig. 148A).
  - (b) Head length  $1/5$  to  $1/3$  body length inclusive (nomocephalic) (Fig. 148B).
  - (c) Head length  $> 1/3$  body length (macrocephalic) (Fig. 148C).
2. Proportion of head depth to length.
  - (a) Head depth (supraoccipital to isthmus)  $< 1/2$  head length (platycephalic) (Fig. 149A).
  - (b) Head depth  $1/2$  to  $1/1$  head length inclusive (mesocephalic) (Fig. 149B).
  - (c) Head depth  $> 1/1$  head length (hypsicephalic) (Fig. 149C).
3. Proportion of "maxillary length" to head length.
  - (a) Maxillary length  $< 1/3$  head length (micrognathic) (Fig. 150A).
  - (b) Maxillary length  $1/3$  to  $1/2$  head length (mesognathic) (Fig. 150B).
  - (c) Maxillary length  $> 1/2$  head length (macrognathic) (Fig. 150C).
4. Proportion of snout length to total head length.
  - (a) Snout  $< 1/4$  total head length (microrhynchal) (Fig. 151C, D).
  - (b) Snout  $1/4$  to  $1/2$  inclusive (nomorhynchal) (Fig. 152A).
  - (c) Snout  $> 1/2$  head length (macrorhynchal) (Fig. 151A, B).
5. Proportion of eye to head length.
  - (a) Antero-posterior diameter of eye  $< 1/5$  head length (microphthalmic) (Fig. 126B, Fig. 119B).
  - (b) Antero-posterior diameter of eye  $1/5$  to  $1/3$  head length (mesophthalmic) (Fig. 137C).
  - (c) Antero-posterior diameter of eye  $> 1/3$  head length (megophthalmic) (Fig. 127B, C, Fig. 123B, Fig. 121A).
6. Proportion of antero-posterior diameter gill chamber to head depth.
  - (a) Antero-posterior diameter gill chamber<sup>1</sup>  $< 1/3$  head depth<sup>2</sup> (microcameral) (Fig. 152C).

<sup>1</sup> Taken from the anterior border of the preoperculum to the posterior border of the operculum, along the horizontal.

<sup>2</sup> Supraoccipital to isthmus.

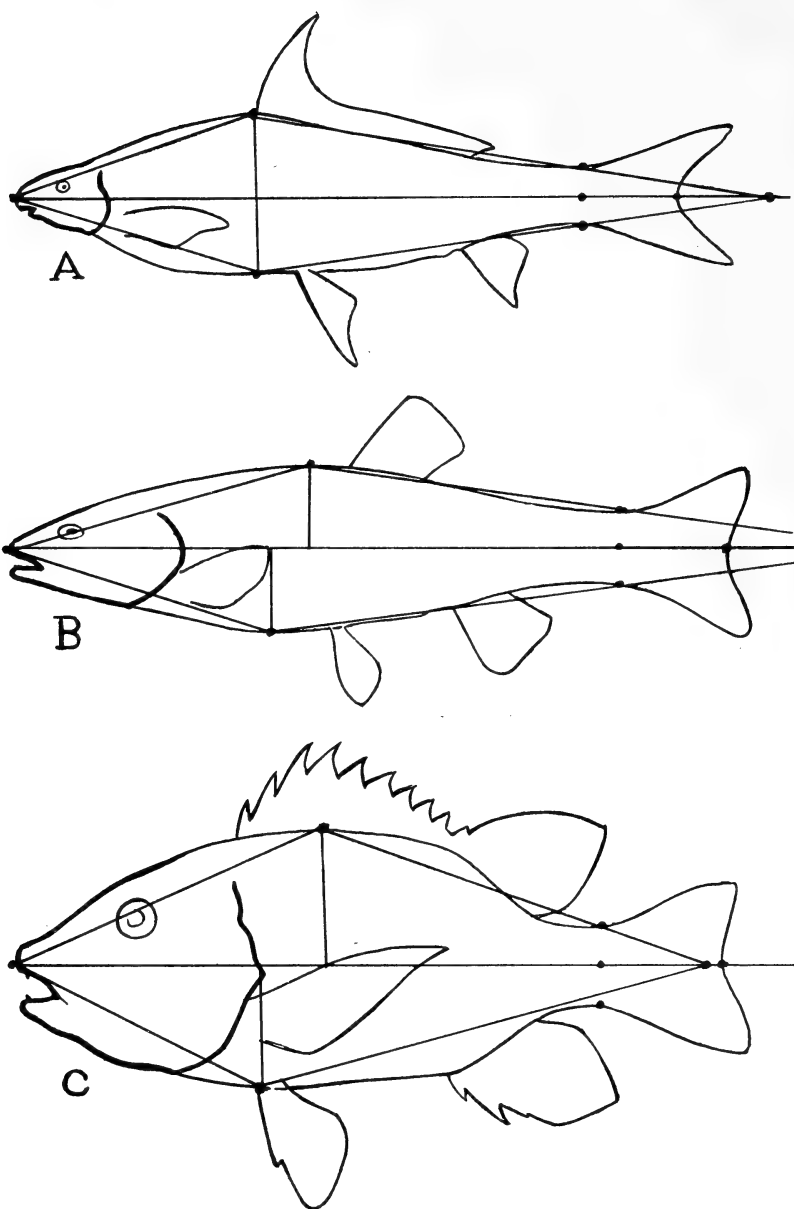


Fig. 148. Varying proportions of head length to body length. A, Microcephalic (*Cycleptus elongatus*); B, nomocephalic (*Semotilus atromaculatus*); C, macrocephalic (*Hoplopagrus guntheri*). Outlines after Jordan and Evermann.

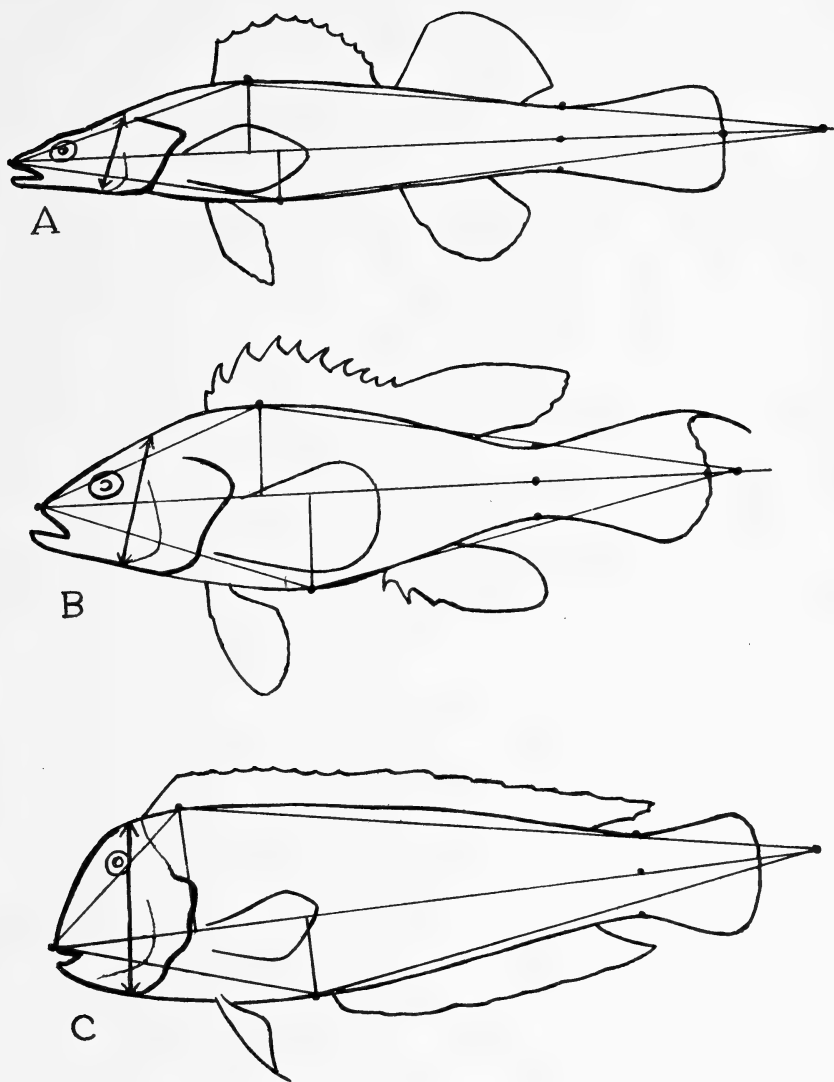


Fig. 149. Varying head depth to head length. A, Platycephalic (*Hypohomus spilatus*); B, mesocephalic (*Paralabrax humeralis*); C, hypsicephalic (*Xyrichtys psittacus*). Outlines after Jordan and Evermann.



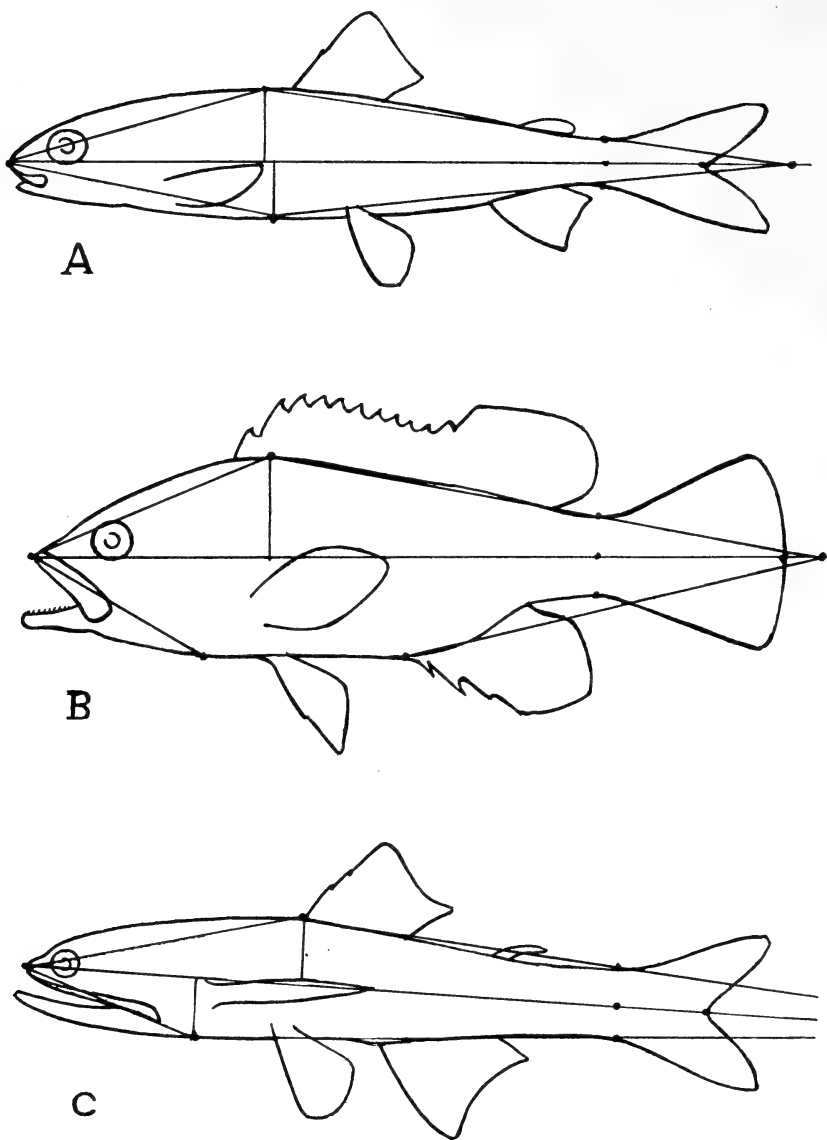


Fig. 150. Varying "maxillary length" to head length. A, micrognathic (*Coregonus williamsoni*); B, mesognathic (*Myxeroperca bouleengeri*); C, macrognathic (*Lampanyctus crocodilus*). Outlines after Jordan and Evermann.

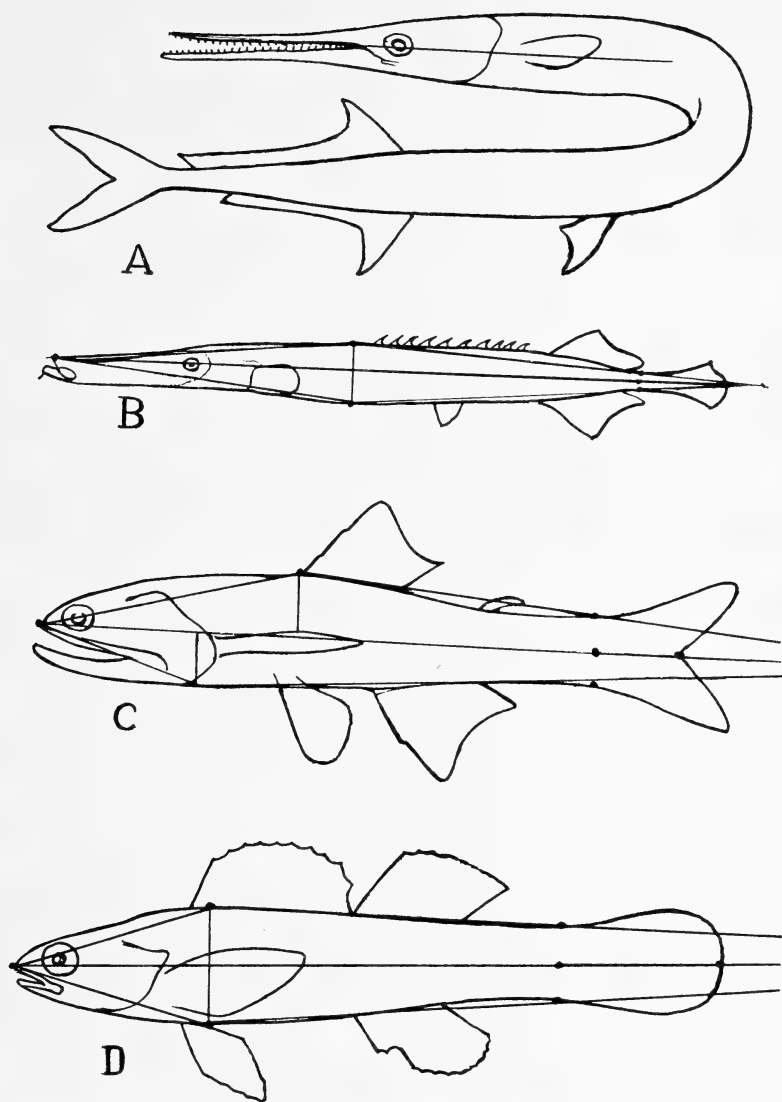


Fig. 151. Varying combinations of different snout lengths and upper jaw length. Long, intermediate or short snouts may be combined with long, intermediate or short jaws, the nine possible combinations all being realized in different fishes. A, Snout long, jaw long (*Tylosurus acus*); B, snout long, jaw short (*Aulorhynchus flavidus*); C, snout short, jaw long (*Lampanyctus crocodilus*); D, snout short, jaw short (*Copelandellus quiescens*). Outlines after Jordan and Evermann.

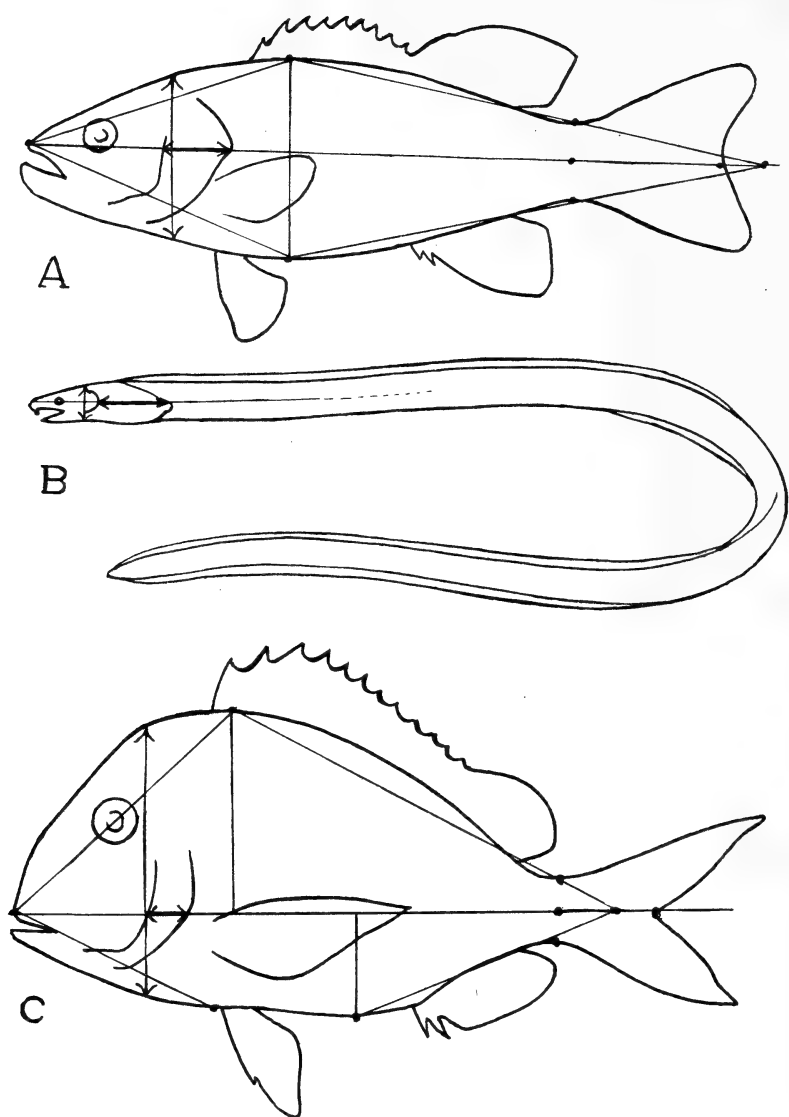


Fig. 152. Varying lengths of branchial chamber to head depth. A, mesocameral (*Micropterus dolomieu*); B, macrocameral (*Bacanichthys scuticaris*); C, microcameral (*Calamus proridens*). Outlines after Jordan and Evermann.

- (b) Antero-posterior diameter gill chamber  $1/3$  to  $3/4$  head depth (mesocameral) (Fig. 152A).
- (c) Antero-posterior diameter gill chamber  $> 3/4$  head depth (macrocameral) (Fig. 152B).

#### IV. *Variable Proportions of Transverse Diameters to Heights.*

1. Proportion of maximum transverse diameter of body, excluding pectoral fins, to body height.
  - (a) Greatest body width  $< 45/100$  body depth (stenothoracic).
  - (b) Greatest body width  $45/100$  to  $1/1$  body depth (mesothoracic).
  - (c) Greatest body width  $> 1/1$  body depth (eurythoracic).
2. Proportion of width across extended pectoral fins to body height.
  - (a) Greatest width across extended pectoral fins  $< 1/1$  body height (stenobrachial).
  - (b) Greatest width across extended pectoral fins  $1/1$  to  $4/1$  inclusive (mesobrachial).
  - (c) Greatest width across extended pectoral fins  $> 4/1$  body height (eurybrachial).
3. Proportions of transverse width of head to height of head.
  - (a) Greatest head width  $< 40/100$  head height (stenocranial).
  - (b) Greatest head width  $40/100$  to  $1/1$  head height (mesocranial).
  - (c) Greatest head width  $> 1/1$  head height (eurycranial).
4. Proportions of snout width to snout depth at nares.
  - (a) Snout width  $< 1/1$  snout depth (stenorhynchal).
  - (b) Snout width  $1/1$  to  $3/1$  inclusive (mesorhynchal).
  - (c) Snout width  $> 3/1$  snout depth (euryrhynchal).
5. Proportionate width of caudal peduncle to its vertical depth.
  - (a) Width caudal peduncle  $< 1/3$  its depth (stenopygidial).
  - (b) Width caudal peduncle  $1/3$  to  $3/4$  its depth (mesopygidial).
  - (c) Width caudal peduncle  $> 3/4$  its depth (eurypygidial).

A much fuller descriptive analysis of the variable factors of the body form of fishes should doubtless be made. For instance, many more terms and measurements describing the shape of successive transverse sections of the body are needed, as well as terms describing the longitudinal sections, together with the diagrams of the sections themselves. But it is hoped that even the incomplete enumeration given above, together with the new terms for describing these variable relations, will facilitate the comparison of different body forms, especially when an attempt is being made to correlate

morphological differences with different modes of function. In fact a vast field of inquiry is open in many directions. With what mechanical and functional conditions for example are hyperdolichosomatic types associated? What are the advantages of having the anal fins subdorsalic in position? How do hypsisomatic types maintain the upright position? Only by a synthesis of the knowledge of the marine engineer and architect with that of the experimentalist, morphologist, the field observer and the student of phylogeny can satisfactory answers be reached.

## PART II. PRELIMINARY REVIEW OF THE EVOLUTION OF BODY-FORM IN FOSSIL AND RECENT FISHES

### 1. OSTRACODERMS, CYCLOSTOMES AND OTHER LOWLY CHORDATES

*The earliest known adaptive radiation of body form in chordates.*—

The known ostracoderms of the Silurian and Devonian were the last branches of an older adaptive radiation that was already under way in the Ordovician and probably began in the Cambrian. With the possible exception of the *Cœlolepidæ*, none of the known ostracoderms could have been ancestral to the later fishes. Nevertheless the group is of extreme interest because it represents a pre-elasmobranch stage of evolution, very probably related to the ancestors of the cyclostomes. Unfortunately little or nothing is known of the body-form of the earliest Ordovician types, but the body-forms of a number of Silurian and Devonian ostracoderms have been accurately restored from excellent material by Rohon, Traquair, Smith Woodward, Kiær and others. The recently published work of Kiær (1924) on the Upper Silurian ostracoderms of Norway has thrown a great light upon the relationships of the entire group<sup>1</sup>.

*The three great orders of Ostracoderms.*—The order Anaspida includes small fusiform fishes with a downwardly turned tail. These are remotely related to the modern cyclostomes, and like them, are monorhinal, with a median nasal opening, followed by a pineal opening; they also have small round gill openings varying from 6 to 15 in number (Kiær.)

The Cephalaspidomorphi (Osteostraci) have the very broad head covered (except in *Ateleaspis*) with a continuous shield. The eyes are dorsal on top of the shield whereas in the more primitive Anaspida, they are lateral. The nasal opening is single and behind it is a pineal opening as in the Anaspida.

The order Heterostraci, according to Stensiö's view, is related to the ancestral myxinoids rather than to the elasmobranchs. In the very primitive *Cœlolepidæ* the depressed body is covered with shark-like placoid scales or denticles, but in the *Pteraspida* the fusiform body is protected by a massive armor or covering of large head

<sup>1</sup> The superb monograph by Stensiö on the Norwegian Cephalaspidæ was received after this paper was in page proof. It proves that the Cephalaspidæ were closely related to the lampreys.

plates without bone cells. Kiær infers that the Heterostraci had paired nostrils and were thus diplorhinal, like the modern elasmobranchs and higher fishes.

*The Anaspida.*—The Anaspida are of extraordinary interest because they appear to be, on the whole, the most primitive known chordates. The body is fusiform, the chief peculiarity being the downwardly turned tail, the tail fin being epichordal exactly as in the ichthyosaurs, thalattosuchians, etc., and the direct opposite of a heterocercal tail. No exact parallel to this occurs in the higher fishes, but it would seem to be well adapted for a fish that perhaps floated inertly or rested lightly on or near the bottom or made brief cycloidal flights in pursuit of small crustaceans which may have been engulfed in the capacious pharynx. The downwardly turned tail may also have been the chief means of maintaining the stability or upright position of the fish. The pectoral fin spines would be lateral balancers and the dorsal spines would serve as small keel plates. The principal lateral thrusts were from the dorsal tail fin and, to a less extent, from the anal fin, which together may have functioned somewhat like the posteriorly displaced dorsal and anal fins of pike-like fishes.

The Anaspida are also of great interest because they show the oldest known stage in the development of scales, dermal rays and spines. The vertically deep rows of lateral flank scales were separated by horizontal septa that apparently correspond in function, with those of modern fishes. From the general correspondence in direction of the scale rows to those of modern fishes, it seems likely that the myotomes of the Anaspida were likewise bent into W-shaped segments.

It is interesting to find that the anatomical points and axes of reference described in Part I as characteristic of later fishes, are more or less recognizable in the body contours of these most ancient known chordates, which doubtless conformed in similar ways to the requirements of gravitation and to stream-line conditions of pressure and friction.

*The Heterostraci.*—Among the Heterostraci, *Pteraspis*, as restored by various authors evidently conforms to normal quadrilaterals in the side, top, bottom and sectional views. Owing to the presence of the hard dorsal and ventral shells and to the apparent absence of dorsal and anal fins, turning movements were probably

slow. The stream-line contours of the shell would seem to be well adapted for fluviatile life and the strongly developed shell may have served as a protection from impacts against stones in the stream.

*Thelodus* and *Lanarkia* are apparently the most primitive of the ray-like Heterostraci, since the body is covered with separate shagreen or placoid scales instead of a more or less continuous shield. As seen from above, the body combines the features of several modern batoids. Thus, they have the unreduced caudal half, and forked heterocercal tail<sup>1</sup> of the Rhinobatidæ, the rounded anterior end and widely separated eyes of *Rhina*, the projecting pectoral tips of *Aëtobatis*. Their quadrilaterals also broadly resemble those of the corresponding modern types, this showing that similar responses to stream line pressures were made on the one hand by the Cœlolepidæ and Drepanaspidæ of the Heterostraci, and on the other hand by the ancestors of the modern rays.

*Drepanaspis* of this order closely parallels *Torpedo* in the rounded form of its disk, but contrasts widely with all batoids in its evident inability to undulate the outer border of the disk. It parallels *Manta* in the great width and toothless condition of the mouth and in the reduction and wide separation of the eyes. The quadrilaterals of all these forms resemble those of their modern analogues.

*The Osteostraci.*—*Cephalaspis* and its allies among the Osteostraci present analogies with *Limulus* in the form of the carapace as well as in the details of their quadrilaterals. Probably all these resemblances indicate similar responses to stream-line conditions.

*Principal types of body-form in the ostracoderms and their modern relatives.*—The principal types of body forms and fins among the ostracoderms, cyclostomes and other lowly chordates may be named and described as follows:

#### Class OSTRACODERMI

##### Order *Anaspida*

Birkenoid: Body fusiform, mesomatic, tail hypobatic and hypocercal (Kiær). A series of dorsal fulcra or ridges, but no dorsal fin. Epichordal tail fin supported by dermal rays. A small anal fin. Pectoral spine or spines. Sides covered with vertically deep rhombic scales, often with peg and socket articulations. Eyes lateral.

<sup>1</sup> Possibly in this case a reversed heterocercal tail, like that of *Anaspida*.



Pharynx capacious, mouth large, terminal, no teeth. Nectonic, fluviatile.

*Pharyngolepis* has a median mandibular jaw plate opposing a kind of incipient beak. Kær thinks it was a predatory form. *Lasanius*, *Euphanerops*, *Pterolepis*, etc., present minor modifications of this Birkenoid type.

#### Order *Osteostraci*

Cephalaspoid: Eurycephalic, head rounded in front, domed, covered with a thin bony shield. Eyes large, dorsal. Body robust, triangular in cross-section, flanks covered with deep scales. Tail heterocercal to diphycercal. Paired pectoral flaps behind cornua of shield. Benthic, fluviatile. *Thyestes* and *Tremataspis* show related types of body form.

#### Order *Heterostraci*

Thelodoid (Cœlolepidoid): Eurythoracic, eurycephalic, macrocephalic, tail macrocercal and deeply forked (possibly reversed heterocercal as in Anaspida). Eyes lateral, small. Small pectoral lappets. Body covered with placoid or shagreen denticles. Benthic, fluviatile.

Drepanaspoid: Essentially as in *Thelodus*, but two large plates on back, long lateral plates and one median ventral plate. Tail large, with the ventral lobe somewhat stronger than the dorsal lobe. Eyes small lateral, mouth very wide, toothless. Benthic, fluviatile.

Pteraspoid: Fusiform; rostrum produced, or short and bluntly rounded. Eyes small, lateral. Massive shield of seven plates homologous with those of *Drepanaspis*. Fluviatile, partly benthic, partly nectonic.

#### Order *Cycliæ*

Palæospondyloid: A well developed endocranium and backbone, the former suggesting the skull of cyclostomes, the latter composed of ring-like centra. Body moderately elongate, ending in a large diphycercal tail which is provided with cartilage (?) rays resembling those of cyclostomes.

#### Order *Cyclostomata*

Petromyzontoid: body anguilliform, cylindrical; pectoral and pelvic fins absent. Dorsal, caudal and anal fin supported by cartilaginous rays. Tail diphycercal. Branchial chamber elongate. Probably a secondarily naked derivative of the stem of the Anaspida. The larval form *Ammocetes* shows evidence of remote relationship with *Amphioxus* and these two forms are probably the nearest living representatives of the ostracoderms.

Myxinoid: Essentially, as in *Petromyzon*, but with degenerate median fins and reduced endoskeleton. Semi-parasitic.

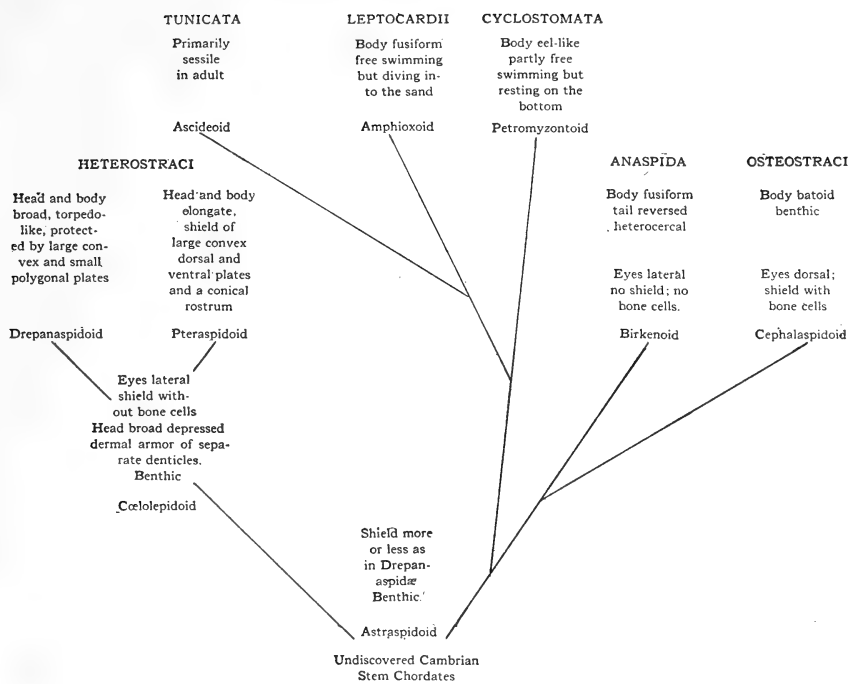


Fig. 153. Adaptive radiation of body form in ostracoderms

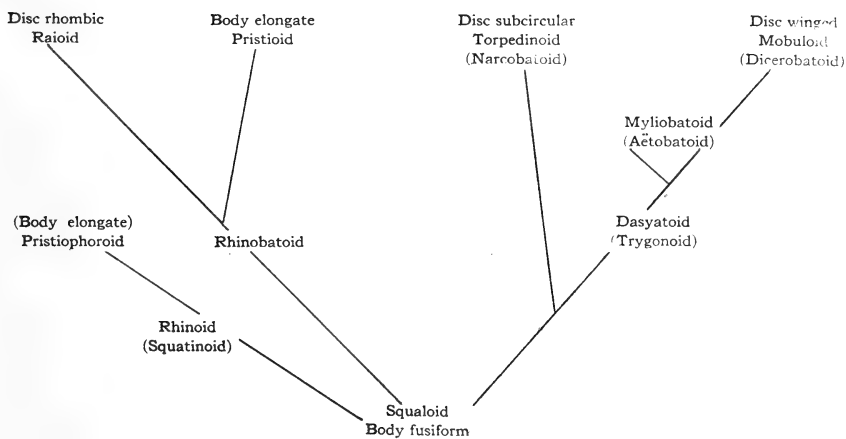


Fig 154. Adaptive radiation of the depressed elasmobranchs

## Class LEPTOCARDII

## (Cephalochordata)

Amphioxoid: body somewhat anguilliform, but head produced into a pointed rostrum, with which the fish dives into the sand. Branchial chamber greatly enlarged with secondary multiplication of gills, and correlated development of atrium. Possibly a naked derivative of some *Pterolepis*-like ostracoderm that was also the ancestor of the cyclostomes.

## Class UROCHORDATA

Ascideoid: The Tunicata probably represent an even further series of specializations and degenerations from the primitive ostracoderm stock, which very early adopted sessile life and finally became colonial, or secondarily free-swimming.

## Class PLACODERMI

Order *Antiarchi*

Pterichthyoid: A domed tortoise-like carapace and flat plastron, covering enlarged branchial chamber; rounded head-shield movably articulated with carapace. Jaw plates of derm bone. Eyes dorsal. A pair of externally jointed pectoral appendages, possibly used in steering. Heterocercal. Fluvatile.

Order *Anarthrodira*

Macropetalichthyoid: Head large covered with derm bones. No joint between head and branchial chamber. Body form unknown, probably *Coccosteus*-like.

Order *Arthrodira*

Coccosteoid: Carapace and plastron of derm bones, covering moderately wide head and enlarged branchial chamber. Head movably jointed to "thorax." Jaws of derm bone, primarily carnivorous. Notochord persistent, cartilaginous neural arches and rods supporting median fins. Tail diphyccercal, no paired fins. Movements tadpole-like.

Dinichthyoid: Essentially coccosteoid but often of gigantic size and with shearing jaws.

Mylostomoid: Essentially coccosteoid but with flattened tritortal plates instead of cutting blades.

*Evolution of body forms in the earliest chordates.*—As already noted the recent results of Kiær and of Stensiö, on the Upper Silurian Ostracoderms of Norway bring us a long way nearer to the solution of the interrelationships of the ostracoderm orders with each other

and with the more primitive existing chordates. At the same time we begin to discern the adaptive radiation of body forms in the ostracoderms. Which came first, the benthic forms with broad depressed head shields or such fusiform free swimming types as the Anaspida? Or was the primitive ostracoderm of Lower Ordovician times more or less intermediate between the two? Unfortunately the geological evidence on this point is hardly decisive. According to Eastman (1917, p. 237), the Middle Ordovician genus *Astraspis* has "large median dorsal and ventral plates of the body armor constructed in the same fashion as the Psammosteidæ out of fused polygonal tesseræ, and the external ornament of these plates is also similar in a general way to that observed in various genera of Heterostracous Ostracoderms." Thus this exceedingly ancient genus *Astraspis* probably had a somewhat depressed and benthic body form, as did the great majority of ostracoderms of nearly all families. On the other hand the Upper Silurian Anaspida were not specialized benthic fishes but fusiform, and at least incipiently free-swimming, although possibly resting on the bottom at times, with the aid of their pectoral fin spines. The frequency of an enlarged gill chamber, a high number of gills and a capacious pharynx are all suggestive of forms that at least rested partly on the bottom as do the cyclostomes and *Amphioxus*. Hence we can hardly accept the current belief that the ancestral chordate was a fully fusiform, nectonic fish. Indeed the prevailing evidence appears to indicate that this fish-like chordate was at least partly benthic in habit and probably somewhat broader in proportion to height than was the case in perfected free-swimming types.

From such a partly depressed, partly bottom-living type, may have been evolved first, the known specialized depressed forms of the Silurian and Devonian, secondly, the anguilliform and more or less degenerate cyclostomes, from the stem of which in turn may have been given off not only the *Amphioxus* group but even the primarily sessile ascidians. In another direction, the partly depressed stem chordate may have given rise to the testudinate antiarchi and arthrodires, while still another branch represented by the known Heterostraci may, according to Kiær, be related to the diplophinal stock of the elasmobranchs and higher fishes.

These inferences are far from being idle speculations. There is a wide field of well known embryological evidence for the relatively

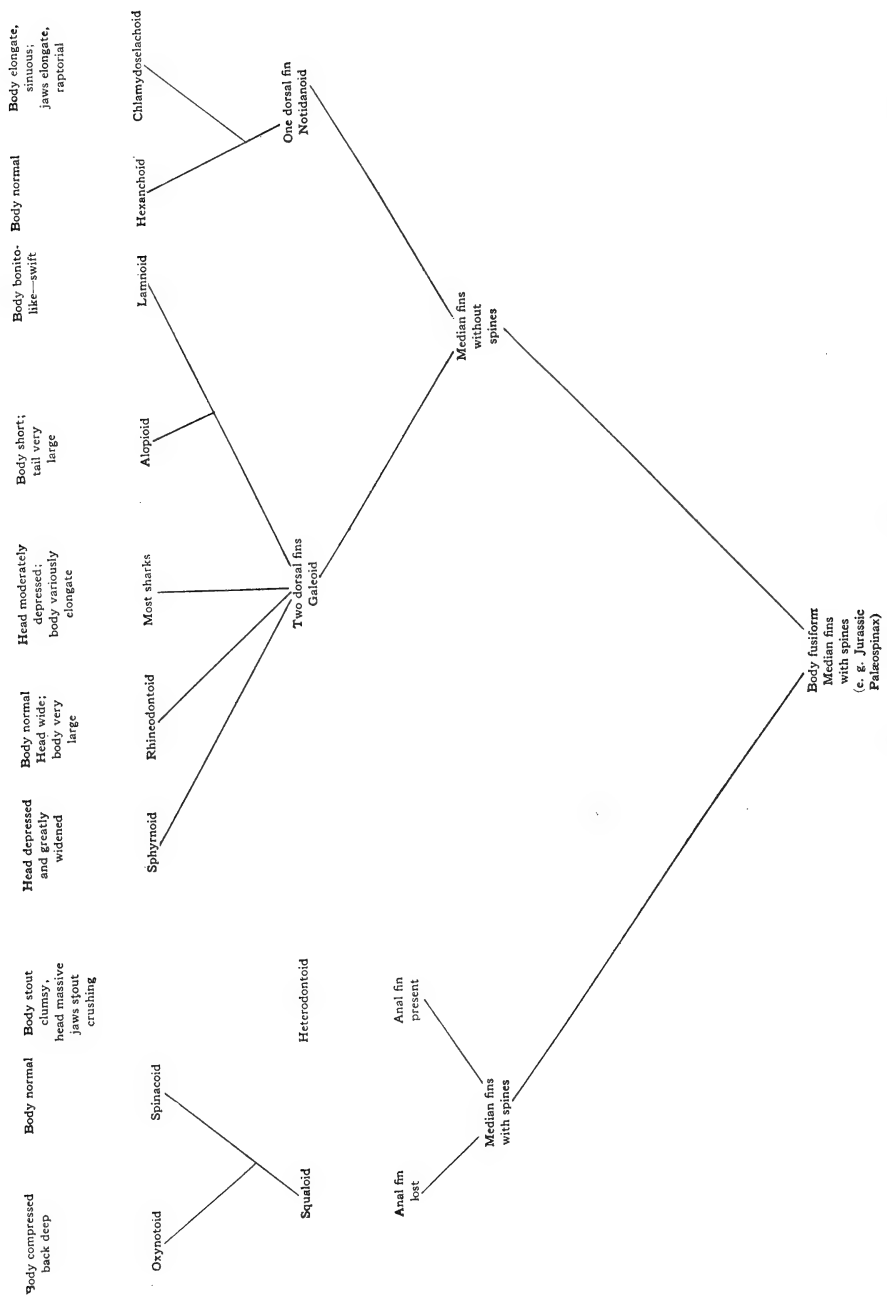


Fig 155. Adaptive radiation of body form in fusiform elasmobranch

close connection of the larval lamprey with *Amphioxus*, and in another direction, equally good evidence for connecting the Tunicata with the *Amphioxus* branch. *Balanoglossus*, on the other hand, is at best remotely related to the true chordates and it may represent another highly retrogressive series from the very base of the chordate stem (Delage and Hérourard).

There is also much negative evidence for connecting the existing cyclostomes with the monorhinal ostracoderms, for there is no other known group from which they could so easily be derived, according to numerous well founded analogies of the derivation of naked anguilliform types from armored and short-bodied ancestors. In another direction, Traquair and Kiær have recognized the elasmobranch affinities of *Thelodus* and *Lanarkia*, which are covered with shagreen denticles or placoid scales, while the ganoid-like scalation of *Birkenia* and the true bone cells in Osteostraci indicate that even the Osteichthyan fishes may be connected with the ostracoderm stock.

## 2. ELASMOBRANCHS

*Body forms and fins of fossil sharks.*—The oldest sharks in which the body-form is known are the little acanthodians of the family Diplacanthidæ. These differed widely from modern sharks in having the body short and relatively deep. Nevertheless the lateral contour was essentially shark-like in the following particulars:

1. The body contour fitted well to a simple quadrilateral frame with nearly equal dorsal and ventral triangles, and with the usual convexity above the entering angle.
2. The tail was heterocercal, the opisthion being located at its posterior border as in many modern sharks.
3. There were two stout dorsal fins located above the postero-dorsal slope, the first being above the apex as is *Heterodontus*; the second dorsal was above the anal.
4. The pectorals, ventrals and anals had their usual positions.

On the other hand a profound difference from modern sharks was the relative immobility of the pectorals and ventrals, which were supported by great rigid spines. All the median fins had little or no free movement and served first in preventing lateral displacement and overturning, and second as fulcrum for the turning and undulations of the body and tail. The pectoral fins, having a dermal shoulder girdle to support them may have been capable of somewhat freer movements.

From this relatively primitive type of acanthodian, A. S. Woodward (1915) has recognized two divergent lines of evolution, one tending toward more massive spines and retaining a short to depressed body (*Diplacanthus* to *Gyracanthus*), the other tending to reduce the spines to a needle-like slenderness and to elongate the body greatly (*Cheiracanthus* to *Acanthodes gracilis*). In this second line of descent the bounding quadrilateral becomes very elongate, the low vertical diameter of the back, together with the relative thickness of the tail, making the slope of the back very slight and bringing the opisthion far behind the uranion. The needle-like fin spines offered little resistance to lateral displacement and no doubt the mode of progression was almost anguilliform.

The Devonian shark *Cladoselache* as described by Dean (1909) shows the following peculiar combination of characters:

1. The body is dolichosomatic, probably lower and wider in cross section than that of typical sharks. The head was certainly low, and fairly broad, with large terminal mouth. The pectoral fins were widely extended laterally and the body fairly low across the pectoral region, with a relatively low first dorsal fin. Thus the head as a whole was probably not unlike that of the living *Chlamydoselache* as were also the jaws and branchial arches.
2. The median and paired fins all had widely extended bases not exerted posteriorly from the body, and supported by radially arranged cartilaginous radials which extended nearly or quite to the tip of the fin. Thus the median and the paired fins were essentially similar in construction and afford strong evidence for the view that both were derived from fin folds (Dean, R. C. Osburn). All the fins served rather as keels and balancers than as paddles.
3. The tail fin was very large externally, homocercal in type and supported by horizontal transverse paired fins on either side of the caudal peduncle, the nearest analogue being the wide lateral keels of the mackerel sharks.

From these data we may conclude that the enlarged tail was the principal propellor, its thrusts being regulated by warping movements of the extended planes of the pectorals, dorsals and ventrals. The wide pectorals served as a relatively stable sling for the sinuous movements of the head and body.

Not much that is definite can be said about the quadrilateral of the body in side view because nearly all the specimens of *Clado-*

*selache* are flattened dorso-ventrally; but its vertical diameter was probably relatively less than in typical modern sharks.

The pleuracanth sharks of the Carboniferous and Permian seem to have been a highly specialized swamp-living offshoot of the cladoselachian stem. The body is much elongated and tapering, especially the dorsal and caudal parts with their fins; the bases of the pectoral fins have become concentrated and the pectoral fins, and to a less extent the pelvic fins, have become paddle-like. Locomotion was doubtless of complex type, in part by means of lateral undulations of the body and tapering tail, in part by independent undulation of the greatly elongate dorsal and caudal fins (after the fashion of *Gymnotus*), in part by paddle-like movements of the pectorals. The skeleton of the peculiar anal fins somewhat resembles that of the small dorsal fin of the ray *Psammobatis* (figured by Tate Regan, 1906, p. 755) in so far as it has a main jointed axis with obliquely branching radials. In both cases these structures have very probably been derived by the crowding together and partial concrescence of the basals and radial cartilages of more normal antero-posteriorly extended fins.

The presence of a large occipital spine, and of massive jaws, as parts of a freely movable head, probably influenced the evolution of strong paddle-like paired fins to assist in the movements of those parts. The enlarged pectoral girdle acts as a sling for the head and thorax and also as a base for the pectoral paddles. As restored by Fritsch and others, the body form of *Pleuracanthus* and its allies in lateral view conforms to an elongate quadrilateral type.

*Body-form and fins of recent sharks.*—The most fundamental characteristics of the body-forms and fins of modern sharks are as follows:

1. As sharks progress by lateral undulations of the entire body, the head being relatively low and offering but little lateral resistance, would sway widely from side to side if it were not checked by the large first dorsal and the pectorals, which form the anterior pivot.
2. The body is dolichosomatic and except for the tail itself, it usually follows closely the inscribed quadrilateral figure. The widest part of the body is often at the posterior end of the lower jaw, where the section is transversely ovoid; sometimes the greatest width is across the base of the pectoral fins where the section is more or less triangular, broadly flattened below and rounded above.



3. The tail which is always heterocercal, has a tendency to depress the head. This is corrected, as noted by Breder, by the pectoral fins and by the flattened lower surface. In certain sharks the caudal axis is sharply raised and the lower lobe of the tail grows downward so that the tail-spread much exceeds the vertical diameter of the quadrilateral and the caudal angle is markedly increased. Thus the tail as a whole approaches the fast swimming scombroïd homocercal type.
4. The upward component of the tail-thrust, tending to raise the column posteriorly and depress the head, is doubtless partly compensated by the relative flatness of the throat and underside of the rostrum, which would tend to push the head upward. Possibly the pectoral fins are in a position to regulate and compensate the opposing thrusts of the head and tail. (Breder). Indeed the alternation and spacing of the fins on the dorsal and ventral sides of the long body have the appearance of balancing it, like weights on a steel yard.
5. The median, and even the paired, fins are much less mobile than those of teleosts and hence retain more of their primitive function of keels and rudders rather than paddles. Hence, as noted by Breder, sharks do not stop suddenly but swerve to one side of an obstacle.
6. The posterior pivot for the posterior part of the body, including the tail, is formed by the ventrals and second dorsal.
7. All the median and paired fins tend to have a convex anterior and a concave posterior border. The convex anterior border offers less resistance to the water than a straight border would, since it is curved backward and its thickness diminishes posteriorly. A convex posterior border would offer more resistance to the water displaced by the fin; a straight anterior border would cause suction at the end; and would push the water ahead of it instead of allowing the water to flow backward; a convex anterior and concave posterior border avoids both these conditions.

Among the most variable factors in the body-form of the sharks are the size and position of the dorsal fins. The anterior dorsal is typically a high keel that collaborates with the pectorals in keeping the fish right side up; it is primitively of large size, located at the summit of the back above the vertical of the quadrilateral, but with its posterior part on the postero-dorsal slope. The first dorsal fin is extremely large in the giant *Cetorhinus maximus* where presumably it aids stability; and very small in *Centroscymnus calolepis*, whose ability to roll over and to move the head laterally may possibly be increased by this circumstance. This first dorsal is often large in

forms with a prominent development of the dorsal lobe of the caudal fin, as in *Gyropleurodus*, *Ginglymostoma*, *Sphyrna*, *Isurus*, *Lamna*, *Cetorhinus*. Occasionally, as in *Scylliorhinus*, *Catulus*, *Pristis*, the first dorsal is shifted backward to lie on the postero-dorsal slope above the ventrals. Such backward displacement of the dorsal increases the relative stability of the posterior slope and tail and increases the postero-lateral thrust of the caudal end of the body.

The second dorsal always lies on the postero-dorsal slope and is often paired with the anal. Pressure on either eyeball of a dying shark will at times cause the posterior borders of the second dorsal and anal fins to be moved simultaneously away from the mid line, a fact which shows that these fins are connected with each other in the brain. At other times pressure on the eye ball will cause movements of the first dorsal. In the *Isuridæ* which have a very large, almost homocercal caudal, the second dorsal and the anal are both much reduced, since the stabilizing function is assumed by the lateral keels.

The pectorals in most sharks lie on or below the antero-ventral slope and thus quite low down on the body, where, as noted by Breder, they compensate the tendency of the caudal fin to push the head downward. The general plane of the pectorals is slightly upturned in front.

The ventrals of sharks lie far behind the vertical diameter of the quadrilateral and near the root of the fleshy caudal part of the body. They also lie in a nearly horizontal plane, and on the postero-ventral boundary line. In addition to their functions of stabilizing and steering, they undoubtedly afford a base for the lateral undulation of the tail.

When the anal fin is lost, as in *Squalidæ*, the ventrals move back below the posterior dorsal, with which they doubtless coöperate. The anal is usually paired with the posterior dorsal. Probably they both steady the lateral movements of the tail as noted above. The anals are reduced in the *Isuridæ* and absent in the *Squalidæ*.

The heterocercal caudal fin of sharks, has been studied by many authors (e. g. Dollo, Schmalhausen, Abel). It is of extremely primitive type, the fleshy part being merely a posterior prolongation of the body and sharing in the latter's undulations.

The flattened underside of the body of sharks also fits well to the quadrilateral frame. The entering angle is always greater

than the posterior, and the widest diameter is well forward, normally either across the pectoral fin bases or across the back part of the lower jaw.

*The Body-form in Depressed Elasmobranchs.*—The quadrilateral outline is equally evident in elasmobranchs of depressed body-form, such as *Pristis* and the skates, in which the principal wedge is horizontal instead of vertical. In the side view, owing to the enormous lateral expansion of the pectoral fins, the entering and posterior angles become small. In *Pristis* (Fig. 131) on account of the great elongation of the snout, and in order to give the head a wide swing from side to side, the pectorals, dorsal and ventrals are moved backward and with them the vertical diameter, which is small in proportion to the horizontal. The edge of the entering wedge is transverse so that the principal pressures due to forward locomotion are above and below.

In Fig. 120D, around the top view of *Rhinobatus* is circumscribed a figure which approaches the posteriorly elongate rhomb of normal sharks. The ventral view presents a similar form, intermediate between sharks and rays.

In the skate-like batoids (Fig. 132) the rhomboid figure that may be drawn so as to touch the end of the tail and the tips of the pectorals becomes empty posteriorly as the pectorals become dominant over the ventral and caudal fins.

In the electric rays (*Torpedo* or *Narcine*) the disc is rounded in front and part of the pectoral muscles are transformed into electric organs. In the Eagle rays (Aetobatidæ, Mobulidæ) and their allies, in which the pectorals have become enlarged into great wings, the transverse diameter of the quadrilateral far exceeds its anteroposterior diameter, and the caudal end of the body is reduced to a long tapering trailer, which possibly assists slightly in turning.

*The Body-form in Chimæroids.*—Passing to the Holocephali (Figs. 137A, 127A) we observe that an excellent account of the movements of *Chimæra collei* has been given by Dean (1906, p. 16). In this highly specialized elasmobranch the head is large to support the powerful crunching jaws. Forward progression is largely by means of the wing-like pectorals, no doubt aided by the lateral undulation of the long tapering body. Consequently the entering angle is large ( $49^\circ$ ), the posterior angle small ( $11^\circ$ ) and the vertical diameter short, compared with the horizontal. The

general body-form thus converges toward that of the macrurids. The body turns upon, and is kept upright by, the high first dorsal and large pectorals. The greatly elongate second dorsal can be undulated antero-posteriorly as well as moved with the caudal prolongation of the body. Contrary to what obtains in many fishes with an elongate dorsal, the anal fin is not paired with the latter, but is conjoined with the lower lobe of the caudal, which is diphyccercal-filiform. When resting quietly in a tank, the fish often drops the tail and rests upon the tips of its downwardly directed paired fins (Dean).

In *Harriotta* (Fig. 127A), a deep sea form which has retained the primitive rostrum of the Mesozoic chimæroids, the ventral vertical deepens with the deepening of the abdomen, and the dorsal vertical and antero-dorsal angles are correspondingly diminished.

*Callorhynchus* in general is far more primitive in body form than *Chimæra*, and is more or less intermediate between the latter and a normal shark type. The Mesozoic chimæroids were not fundamentally dissimilar from their modern relatives.

*Summary of Body-forms of Elasmobranchs.*—The principal body forms of ancient and modern elasmobranchs (including the chimæroids) may accordingly be listed as follows:

Acanthodoid: Mesosomatic to dolichosomatic; essentially galeoid (see below), but with relatively immobile fins supported by prominent spines.

Cladoselachoid: Dolichosomatic, body probably wider than in most modern sharks. Essentially galeoid (see below), but with tail pseudo-homocercal and supported by lateral keels. All fins keel-like and mobile, permanently erected, but with serially disposed supporting rods of cartilages which were doubtless used in warping the surface of the fins. Dorsal fins two, the first with (*Ctenacanthus*) or without (*Cladoselache*) a supporting spine.

Pleuracanthoid: Dolichosomatic, essentially galeoid (see below), but with greatly elongated dorsal fin, long diphyccercal tail, enlarged biserial paddle-like pectorals and extended uniserial pelvic fins. A large erectile nuchal spine.

Heterodontoid: Mesosomatic, tail heterocercal. Head thick-set to support powerful crushing jaws; two dorsals with strong spines firmly supported on the back bone by cartilage bases.

Galeoid: body fusiform, dolichosomatic; head more or less depressed; tail heterocercal; paired fin well developed. Two dorsals without spines. Sinuous movement pivoted on prominent dorsal, pectoral and ventral fins. Free swimming, mostly pelagic.

Notidanoid: Dolichosomatic, essentially galeoid, but with only one dorsal.

Chlamydoselachoid: essentially notidanoid but hyperdolichosomatic.

Lamnoid: essentially galeoid but body bonito-like; large tail with well raised caudal axis supported by lateral fin folds. Posterior dorsal and anal fins much reduced. Swift swimming, pelagic.

Alopioid: essentially lamnoid but with heterocercal tail greatly lengthened: body short and thick; head relatively small and conical. The long trailing and lashing tail is used in rounding up the schools of small fish upon which the "thrasher" feeds.

Sphyrnoid: essentially galeoid but with head much widened, depressed and shortened antero-posteriorly. Movements galeoid, but with ability to make sudden dives and quick turns by means of the horizontal keel formed by the flattened head.

Squaloid: essentially galeoid, but without anal fin, and with a strong spine on each of the two dorsal fins.

Oxyntoid: essentially squaloid but with the back greatly deepened.

Rhinobatoid: intermediate between the galeoid and raoid forms: *i. e.*, body depressed anteriorly, pectorals expanded laterally but much less so than in raoids, post-pectorals part strongly developed, tail heterocercal. Gill slits inferior; mostly bottom-living.

Pristioid: essentially rhinobatoid but with the rostrum greatly produced and armed on either side with a row of socketed teeth.

Rhinoid (squatoid): essentially squaloid but euryomatic, and eurybrachial with laterally extended pectoral fins. Tail heterocercal, well developed.

Raoid: body depressed (euryomatic), more or less rhombic in top view, due to the great lateral expansion of the pectorals, which grow forward to the end of the snout and backward to overlap the ventrals; post-pectoral parts reduced. Locomotion chiefly by means of enlarged pectorals. Typically bottom-living.

Torpedinoid (Narcobatoid): body depressed, more or less circular in top view, the widely expanded pectorals partly modified into an electric organ. Post-pectoral parts not reduced.

Dasybatoid: body depressed, euryomatic, the disc subquadrangular to subcircular, tail long whip-like with a strong serrated spine.

Mobuloid: body depressed extremely euryomatic, the disc becoming nearly twice as wide as long. Tail reduced to a long thin trailer.

Myriacanthoid: somewhat galeoid in type, but with rostrum greatly produced and with large spine on dorsal fin. Pectorals paddle-like, with lobate fleshy base.

Callorhynchoid: essentially myriacanthoid but with shortened and flexible rostrum and reduced dorsal spine. Tail heterocercal.

Chimæroid: essentially callorhynchoid, but with shortened conical rostrum, head large, steadied by prominent first dorsal fin, which is supported by a strong spine. Paddle-like pectorals and pelvics dominant over relatively feeble tail; second dorsal, with greatly elongate base cooperating with elongate filiform tail.

Rhinochimæroid: essentially chimæroid but with elongate rostrum.

Harriotoid: rostrum greatly produced, abdomen very large. Otherwise much as in *Rhinochimæra*. A deep water form.

### 3. CHONDROSTEI, HOLOSTEI AND TELEOSTEI

#### Chondrostei

In the Devonian and Carboniferous Pæoniscidæ, which stand at the very base of the ganoid-teleost series, the body-form conforms to the ordinary quadrilateral types, in which the part behind the vertical is moderately produced and the opisthion is well behind the uranion. The entering and posterior angles vary in the different genera with the height of the body. In the Devonian *Cheirolepis*, a prototypal forerunner of the whole osteichthyan series, the body-form is moderately dolichosomatic with all the fins of small to moderate size; the caudal fin was completely heterocercal and body movements were doubtless shark-like. The jaws are large and the fish was doubtless a comparatively swift predatory type.

In *Palæoniscus* the single dorsal lies on the dorso-posterior boundary just behind the dorsal vertical. It is thus in a pivotal position both for keeping the body upright and for assisting the pectorals in lateral turning. All the fins except the caudal are relatively small as compared with those of most teleosts, and it is evident that the principal method of progression was by lateral undulation of the body. Moreover the fin rays in all the fins are barely differentiated from the body scales, and very likely the fin muscles were less differentiated from the body muscles than they are in later fishes. In *Amblypterus* the fins are larger. The head of *Palæoniscus* is neither depressed, as in sharks, nor compressed, as in many teleosts, but rounded anteriorly, and it could evidently be pushed readily in any direction. The jaws are large and of carnivorous type but with delicate teeth. *Palæoniscus* seems relatively inefficient in stopping suddenly, since its pectorals and dorsal are small. The large heterocercal tail would seem to have the tendency to push the head downward but this may have been

corrected by contrary bendings of the body and by the bluntness of the snout.

In swimming the head must have swung from side to side through a larger arc than is the case with compressed teleosts with large heads. This is evidenced by its small size, its relatively large distance from the dorsal fin, and the small size of the pectorals, which in higher fishes steady the head.

The scales of the older ganoids did not overlap posteriorly and the body may have been less flexible than it is in smooth-skinned fishes, but on the other hand the vertebral centra were but feebly developed and the vertebral axis may have been quite flexible, the main strengthening being by means of the scales. *Amblypterus*, *Trissolepis*, *Coccolepis*, and *Eurynotus* had larger fins than did *Palæoniscus* and to this extent they foreshadow the modern teleosts.

The Platysomnidae were small-mouthed or nibbling, more or less deep-bodied fishes which were derived directly from typical palæoniscids, the body finally becoming very deep and compressed, the circumscribed quadrilateral becoming almost a square. The deepening of the body increases the strength and sturdiness of the fish, giving power to pluck small organisms from the rocks. Hence the entering and posterior angles increase with the depth, the dorsal and anal fins become greatly elongated on the posterior boundaries of the quadrilateral, opposing each other as they do in many later deep-bodied fishes; and no doubt they served primarily as keels and rudders. By undulations running up and down along their borders the dorsal and anal fins must have started successive series of pressures, the general directions of which would have been transverse to the mid-plane. If both dorsal and anal undulations were towards the rear at the same moment, the resultant pressure would be in an anterior direction, as in deep-bodied carangids. On the other hand, if the undulations along the dorsal and anal fins were passing in opposite directions, the resultant torques would tend to rotate the body in a vertical plane. The short truncate pectorals are evidently sufficient both for steering upward and downward and for turning, the ventrals being absent. The tail, also as in carangids, is large and lunate doubtless for the same reasons (cf. Breder, 1926) as in modern fishes. Some of the less specialized platysomids parallel the deep-bodied Sparidae, having a high, arched back, a deep head and shallow abdomen. Here the pectorals are enlarged, possibly to prevent overturning.

*Dorypterus* is another deep-bodied Chondrosteian, the sole known genus of a distinct family which, to some extent parallels certain Pycnodontidæ (cf. Abel, 1919, p. 194; Gill, 1925). It is hypsisomatic and hypsigastric, with a very high projection of the dorsal fin, elongate, functionally paired dorsal and anal and a deeply forked tail. Thus, as noted by Gill, this genus was of the deep-bodied coral-fish type. The difference in height between the anterior and the posterior verticals being great in proportion to the horizontal distance between them, the postero-dorsal slope is steep and the opisthion is close behind the pygidion and well in front of the uranion as in some other deep-bodied fishes. Beneath the anterior part of the dorsal fin there are one or two endoskeletal fin-supports for each epineural arch; beneath the elevated process of the fin there were two such supports for each epineural block, while beneath the posterior half of the fin there were three for each block. In the anal fin there was no exact correspondence between the endoskeletal fin supports and the hypural blocks. There was also no correspondence between the endoskeletal fin supports and the far more numerous dermal rays of the fins. Hence we may perhaps infer that in this fish as in the earlier Palæoniscidæ the erector and depressor muscles of the fins were incompletely differentiated from the great myomeres of the flanks which bent the back bone.

The Catopteridæ were Triassic derivatives of the Palæoniscidæ which progressed toward the higher grade of evolution by changing the tail from a heterocercal to a hemi-heterocercal type, but they retained a primitive palæoniscoid type of skull, while their more progressive relatives, *Acentrophorus* went on to the next higher grade represented by the Semionotidæ. The body is elongate fusiform as in many later forms, the opisthion lying far behind the uranion. The dorsal and anal are large, opposed to each other and placed well behind the vertical, this condition permitting a wide lateral movement of the head. The caudal fin is large and almost homocercal, its vertical diameter equaling that of the body. The upward turning of the vertebral axis in the tail indicates that the subvertebral proximal tail muscle was beginning to point obliquely upward and backward as in modern ganoids and that the power of the tail to start undulatory movements of its own was increasing. With this upturning the principal thrust of the tail fin is no longer upward but more antero-posterior in direction.



The Jurassic *Chondrosteus* is structurally intermediate between Palæoniscus and the modern sturgeons (Woodward, Watson). It has progressed beyond the former in the elongation of the body, increase in size of all the fins, reduction of the scales, withdrawal of the mouth beneath the well developed snout. Its quadrilateral is not dissimilar to that of *Acipenser brevirostris*, except that the vertical is further forward. The single dorsal lies above the ventrals and is not opposed to the anal as it is in *Acipenser*. In the latter the body form is elongate-rhombic, with a low vertical diameter. The opisthion is near the pygidion. The posterior position of the ventrals, dorsal and anal, imply a wide lateral swing of the head which is somewhat flattened on the under side. The slight upward slope of the under side of the head, producing an upward counter thrust from the water, is probably sufficient to compensate for the downward component of the thrust from the heterocercal tail. The function of the rows of dorsal and lateral scutes, which have replaced the body scales, is not clear, unless they aid as keels in preventing the body from rolling over. The sturgeon from the position and form of its mouth is evidently a bottom-feeding form, which moves slowly and needs to maintain its position in spite of currents. This ray-like tendency is further expressed in *Scaphirhynchus* with its low depressed snout.

The Spoonbill (*Polyodon*) and its relative *Psephurus* have evidently been derived from a form like the Jurassic *Chondrosteus* by the great development and flattening of the snout and elongation of the mouth, the fins remaining much as they were, except for the further enlargement of the dorsal and anal. These now are shifted back near the tail as in other long snouted forms, and facilitate the side swinging of the enormous rostrum. The under side view of *Polyodon* shows how the rostrum and body-form alike conform to stream-line requirements. As in the batoids the under-side view as a whole represents two quadrilaterals conjoined, an anterior one including the lateral expansion of the rostrum, and a posterior one including the axis of the rostrum and the body itself. The pectorals are weak, but the posterior fulcra for lateral bending (dorsal and anal) are strongly developed.

## HOLOSTEI

*Acentrophorus*, the Permian forerunner of the Holostei is transitional in the form of its tail between the heterocercal palæonescoids and the abbreviate-heterocercal Semionotidæ. The three species recently restored by Gill (1923) vary from mesosomatic to sub-hypsisomatic in proportions. The single dorsal lies on the postero-superior slope, behind the dorsal vertical and is functionally paired with the well developed anal. The pectoral and ventral fins are not large but the tail is large and lunate to truncate. Each fin ray has a single endoskeletal supporting rod, so that the muscles for erecting the fins must have approached the modern conditions. The mouth is small, the eye fairly large. These must have been quick turning fishes.

*Dapedius* carries further the tendency to deepen the body, which culminates in the Pycnodontidæ. Here it is almost rhombic in form. The dorsal and anal are increased in length and oppose each other on the posterior boundaries of the quadrilateral, no doubt acting together to produce slow forward or backward movements. More rapid movements were doubtless executed by lateral undulations of the body and by thrusts of the broad tail, which is externally homocercal. The latter, however, was not fastened so efficiently to the back bone as it is in later fishes with expanded hypural bones.

The back-bone has an anterior convexity above the swim-bladder and body cavity, and a posterior concavity that runs up into the heterocercal tail. Possibly this sigmoid flexure, which is often present in deep-bodied fishes, may have strengthened the backbone against the opposing thrusts of the body and of the medium; it may also have served as a spring to oppose undue crumpling of the body by the myomeres. But very possibly the principal reason why the backbone arches upward anteriorly is to bring it above the swelling swimbladder, while the reason why it slopes downward posteriorly is to bring the tail thrust directly behind the centre of gravity, which is located in the swim bladder, and below the anterior part of the column. Finally the terminal upturning of the column may be a response to the upward component of the thrust of the internally heterocercal tail.

The more specialized pycnodonts parallel later deep-bodied

fish such as *Platax* and the Ephippidæ. The dorsal and anal fins are shifted posteriorly so that their bases are steeply inclined to the horizontal and their thrusts are at about  $45^{\circ}$  to it. The caudal is broad and externally homocercal. As in other deep-bodied fishes the ventrals are reduced, their normal functions, including that of assisting in keeping the body upright, being taken over by the dorsal and anal fins. No doubt this powerful apparatus gave a firm stance in plucking up the shelled molluscs upon which the pycnodonts probably fed.

*Lepidotus* of the Semionotidæ was a medium to stout-bodied more or less Hæmulid-like fish with relatively smaller and less efficient fins than those of modern heavy bodied teleosts. The bounding quadrilateral comes close to the body except on the antero-dorsal convexity. The dorsal fin is displaced to the postero-dorsal slope and opposes the anal. The tail is hemi-heterocercal.

The modern *Lepidosteus* may be regarded as a long-bodied, long-snouted derivative of a *Lepidotus*-like holostean.<sup>1</sup> As in many other predatory forms with an elongate snout the horizontal is long as compared with the vertical and both entering and posterior angles are small. The anterior dorsal vertical being relatively far forward from the posterior vertical and the difference in height between them not great, the postero-dorsal slope is gentle and the opisthion is well behind the uranion. The posterior vertical axis of turning, which runs through the opposed dorsal and anal, is moved very far back, which gives a wide lateral sweep to the elongate snout together with quick turning ability. The well developed ventral fins lie nearly in the middle of the body and no doubt coöperate with the pectorals in vertical changes of direction. The broad diphycercal tail gives a powerful thrust against the water.

Rather similar proportions obtained in the Mesozoic Aspidorhynchidæ, which were amioid analogues of *Lepidosteus*. The fins however are smaller.

*Caturus furcatus*, a Jurassic amioid, as restored by Smith Woodward, was a swift, evidently predatory fish with carnivorous jaws and large forked tail, the spread of which considerably exceeds the vertical diameter of the body. The general contour conforms perfectly to the normal quadrilateral type. The other fins are smaller than in modern fishes of similar body form. The length of

<sup>1</sup> cf. Goodrich '09, pp. 342, 344.

the body, to the fork of the tail, is a little more than four times its depth. As shown by inspection of the endoskeletal supports of the fins, the fin muscles of the dorsal, anal and ventral fins were completely differentiated from the vertebral muscles of the flanks.

*Hypsocormus insignis* is a more specialized predatory amioid than *Caturus*, with a deeper body, in which the length is only a little more than three times the depth. The tail is very large and deeply forked and the fish was evidently a swift swimming form. In response to the deepening of the body the dorsal and anal fins have become larger and more extended posteriorly, as compared with those of *Caturus*, and they have also tended to supersede the ventrals which are decidedly reduced.

The modern *Amia*, a modified descendant of the Jurassic *Megalurus*, has departed widely from the more primitive body-form represented in *Caturus*. The leading feature is the elongation of the body and especially of the dorsal fin, which can be thrown into antero-posterior undulations producing slow forward or backward progression (Breder). The tail also is strongly built and convex with a deep, thick peduncle. The result of these conditions is that the posterior dorsal vertical is but slightly less than the anterior dorsal vertical, consequently the slope of the dorsal fin base is slight and the opisthion is thrown far to the rear. The pectoral and pelvic fins have remained small (contrast the much larger fins of typical teleosts) and occupy about the same relative positions that they did in *Caturus*. The anal fin has increased a little, but the partly heterocercal caudal fin has become broadly diphyccercal instead of lunate, thereby probably gaining a more powerful thrust in a forward and upward direction, possibly to oppose the forward and downward component of the dorsal, and thus produce forward locomotion.

The principal types of body-form among the Holostei may be listed as follows:

Palæoniscoid: the most primitive ganoid type, body mesosomatic, fusiform, movements essentially galeoid; pivoted on single dorsal, small pectoral and ventral, moderate anal; tail large, heterocercal, bifurcate; median fins incipiently erectile and but little extensible; hence turning and stopping movements probably less rapid than in typical teleosts. Stream-living.

Platysomoid: a deep-bodied (hypsosomatic) derivative of the palæoniscoid type; elongate dorsal and anal, on posterior slopes,

doubtless important in turning movements, but not as strongly constructed as in deep-bodied teleosts.

**Dorypteroid:** a deep-bodied derivative of the palæoniscoid type, with excessively high dorsal fin.

**Chondrosteoid:** intermediate between palæoniscoid and acipenseroid types; as compared with the former the body more elongated, all fins larger.

**Polyodontoid:** a long-billed modification of the chondrosteoid type.

**Acipenseroid:** an armored derivative of the chondrosteoid type but with the snout produced, the dorsal fin shifted backward, above the anal, and the pectorals strengthened by a stout bony anterior ray; tail heterocercal; movements essentially galeoid.

**Semionotoid:** body fusiform to moderately deep, compressed, more or less sparid-like; single dorsal on postero-superior slope opposing anal; tail strongly developed, externally homocercal, lunate. Stream-living.

**Dapedioid:** body becoming orbicular; a deep bodied derivative of the primitive semionotoid type. Tail externally homocercal, truncate. Inshore fishes with small mouths.

**Tetragonolepoid:** an extremely bathygastric derivative of the primitive semionotoid type.

**Pycnodontoid:** a hypsisomatic derivative of the semionotoid type differing from the dapedioid from in the additional bracing of the vertebral column.

**Lepidosteoid:** dolichosomatic derivative of the semionotoid type, with elongate rostrum, posteriorly displaced turning fins (dorsals and anals) and powerful convex tail. Predatory, stream-living. Paralleling the esocoid type.

**Macrosemioid:** derived from primitive semionotoid form by elongation of the body and elongation and enlargement of the dorsal fin.

**Caturoid:** possibly derived from primitive semionotoid type by moderate elongation of body and of jaws; dorsal fin moderate, near summit of back; caudal fin large, ventral and anal small.

**Pachycormoid:** swift-swimming derivative of the caturoid type, with moderately deep back, very large furcate tail, delicate peduncle, moderately elongate anal, moderate dorsal, reduced ventral and moderate pectoral.

**Euthynotoid:** elongate almost Coryphæna-like derivative of the pachycormoid type.

**Protosphyrænoid:** a derivative of the pachycormoid type with an elongate pointed rostrum and enlarged pectoral fins with serrate anterior border.

**Oligopleuroid:** body form similar to caturoid type but with centra better developed.

Amioid: a moderately elongate derivative of the caturoid type; *Megalurus* with more normal dorsal, *Amia* with greatly elongate dorsal, capable of strong longitudinal undulations; tail spatulate; pectoral, pelvic and anal fins moderate. Stream-living.

Pholidophoroid: more or less herring-like derivatives of a primitive short-bodied (disciform) type (Abel); body moderately elongate, fins small.

Thoracopteroid: a flying-fish derivative of the pholidophoroid type, with greatly enlarged pectorals and strongly developed hypochordal lobe of the caudal fin. (Abel.)

The body-forms of a few representative teleosts are listed on p. 414.

#### TELEOSTEI

The body-forms and fins of teleosts will, it is planned be discussed more in detail in later numbers of this series, but in the present paper I would like to record several incidents that have come under my observation which suggest the complexity of the locomotor apparatus in the higher teleost fishes and the marvellous quickness and precision of their movements. The first incident was observed in the aquarium at Honolulu in 1921 by Mr. H. C. Raven and myself and is thus related in "Natural History," 1921 page 555: "There were a number of 'Akilolo' wrasses (*Julis pulcherrima*) in one tank swimming about very actively. As we approached, one of them suddenly emerged from the sandy bottom where he had been lying buried, and immediately another made a dash at him but missed him. Then began a chase of dazzling quickness and intricacy. The two fishes flashed back and forth, up and down, dodging and turning like a couple of brilliantly colored flies, and it seemed a marvel how they steered clear both of the rocks in the center and of the sides and bottom of the tank. After some seconds the pursuer succeeded in nipping and breaking off parts of the dorsal fin of his victim, evidently damaging the latter's steering gear and causing him to tilt and wobble in his course. The pursued then dived into the sand, covering himself completely. The aggressor hung around awhile, nosing about and evidently waiting for another chance to attack, but after returning to the spot several times, finally gave it up.

"From the viewpoint of comparative anatomy this incident is instructive, because it affords an example of very complex actions, having the appearance of being guided by intelligence, but con-

trolled by a brain which entirely lacks the highly developed 'cerebral hemispheres' of mammals and birds."

The second series of observations was made by me upon various small fishes living in the tide pools in the Galapagos and Cocos Islands. In trying to net these fishes, including the young of pomacentrids, gobies and wrasses, I often noticed the, at first sight, reckless way in which they hurled themselves about, but at the same time avoided the net and darted through the smallest crevices without striking themselves against the rocks. When the waves dashed into the tide-pools they were equally able to take care of themselves and it was evident that their speeds considerably exceeded those of the waves and currents by which they were buffeted. Whenever one of our party went below the surface in the diving helmet the fat-bodied pomacentrids would crowd around to look at the big stranger. But such was their skill and quickness in dodging that they, and indeed most other fishes, offered difficult targets for our three-pronged spears. Thus both short-bodied fishes, like pomacentrids and chaetodonts, and long bodied forms, including wrasses, scarids and morays, were usually successful in evading capture and in avoiding injury from the waves and currents. On the other hand we never saw very small sharks in rocky tide pools and this fact seemed in keeping with the unquestionable superiority of the teleosts not only in the greater size and extensibility of their fins but especially in the far more advanced development and complexity of the optic centers of their brain, which form the dominant organs in coördinating visual impressions with motor responses.

The third series of observations was made by Mr. Dwight Franklin and myself on living specimens of the Sargasso fish (*Pterophryne historio*) in aquaria on board the "*Arcturus*." *Pterophryne* is a short and fairly deep, thick-set, carnivorous little fish, with a very small upturned mouth and great handlike pectoral fins with movable elbows; it has a prominent backwardly extended dorsal fin and downwardly projecting ventral fins that end below in large white "feet." Its golden-brown ground-color with irregular patches of dark brown, flecked with little white circular spots, form a perfect camouflage as the fish lurks on the gold and brown weeds.

When swimming slowly the principal thrusts were caused by the

rhythmic jets of water from the small rounded gill openings,<sup>1</sup> modified by the gentle undulations of the pectoral fin membranes.

When crawling along the branches of the weed the *Pterophryne* sometimes moved as if it were stalking the alert little fishes and crustaceans upon which it feeds. One long pectoral flipper would be slowly swung forward while the opposite one was moving backward, the body being supported below by the large white feet, which turned outward and shuffled away in the well known manner of the cinema comedian.

When resting in the weed the fish maintained his position with all four paired fins and with as many median fins as could reach parts of the weed. One huge pectoral "arm" would be extended almost straight upward, the finger-like tips of the dermal rays clutching a branch of the weed that hung down above the fish; the opposite pectoral was thrust downward and reflected at the "wrist," the "palm" turned outward and forward and the palmar side of the "fingers" touching weed. One long "foot," following another branch of weed, was cocked forward and upward; the other, reaching still another branch, was directed backward and downward. The posteriorly elongate part of the dorsal was folded over and served as another prop, and at other times the caudal and anal fins also coöperated in keeping the fish securely placed in spite of the movements of wind or wave.

But it would be a mistake to infer that *Pterophryne* was always a sluggish, slow moving fish. When one of these fishes was placed in a large pan and attempts were made to catch it by hand it made great flying leaps, such as it may have made in sudden dashes after its prey or in overtaking the weed after brief excursions.

Thus the pediculate teleost *Pterophryne* seems to be near the acme of functional and structural differentiation of the parts of the locomotor apparatus.

## SUMMARY AND CONCLUSIONS

### 1. *Relations of Body-form to Gravity*

It has been shown in this paper that the body-contours of fishes have certain normally constant relations to quadrilateral

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<sup>1</sup> These are not homologous with the regular opercular openings of ordinary fishes, but represent a secondary opening at the end of a dermal groove, or tube, that conducts the exhaled water to an exit *behind* the pectoral fin.



figures drawn around them. The causes of this fact are doubtless extremely complex, but a few of the more fundamental ones are discernible:

(a). Nearly all organisms are differentiated with reference to the direction of gravitation, into a dorsal and a ventral side. Thus in fishes the apex, the gasterion and the horizontal plane (as defined above) are anatomical expressions of this primary differentiation.

(b). It is not improbable that radiate symmetry is older than bilateral symmetry and is the result of equal growth in all directions from a centre in the horizontal plane. Anteroposterior differentiation into head and tail ends, whether initiated through the assumption of a bottom-living and creeping habit or in some other way, is normally associated with movements in planes, the average direction of which would be tangent to the earth's surface and at right angles to the dorso ventral axis of gravitation. The anatomical points here named prosthion and pygidion dexterion, aristerion, (p. 334, 340) which are thus oriented to cosmic forces, reach their definitive positions through differential growth, which, starting from a single cell in the centre, is normally faster in the horizontal than in the vertical axis.

(c). Bilateral symmetry and the existence of all the points and axes of reference herein named are also conditioned by the fact that fishes move in a medium that offers resistance to antero-posterior movement both through pressure due to gravitation and through friction. It is well known that what are called stream-line forms are the most efficient either in deflecting an oncoming stream or in pushing aside the water in forward locomotion. Stream-line requirements in short are responsible for the universal functional and structural differentiation of normal fish body-forms into an entrance and a run, and it is for this reason that the body-forms of fishes fit so nearly into the elongate rhomboid figures described in this paper.

(d). Stream-line contours in fishes are produced by differential growth in the three primary planes, resulting in the observed relations and proportions of the entering and posterior angles, of the dorsal and ventral verticals, of the transverse diameters, etc. Also the observed curvatures of the forehead, back, tail, abdomen, and throat, as well as the form and relations of all the fins, are apparently in harmony with stream-line requirements. Breder (1926) has

shown very fully how the high pressure areas produced by the undulation of a fish's body and tail are passed backward faster than the fish moves forward and thus produce a backwardly flowing stream. The stream-line tapering of the body toward the posterior end, which makes the posterior angle of the quadrilateral less than the entering angle, is doubtless conditioned by the complex pressure and suction effects both of the water displaced by the head and the backwardly flowing stream of high pressure areas.

Parsons (1888) has shown that in typical fishes the greatest cross section of the body cuts the horizontal line at a distance behind the tip of the snout equal to thirty-six percent of the distance from the snout to the tail base. The exact positions of the apex and gasterion, dexterion and aristerion, and of the dorsal and ventral verticals of the bounding quadrilaterals, are thus adjusted to produce the conditions noted by Parsons and by Breder.

## 2. *Relations of Body-form to the Form and Placement of the Fins*

In considering the action of the several fins upon the body and the relations of the fins to the bounding quadrilateral, let us assume for a moment that the body is rigid and that its whole weight is concentrated at its centre of gravity, which is frequently located in the swim-bladder in the anterior part of the thorax (Breder). Then the torques or moments of force of each fin are the components of muscle forces that are at right angles to lines drawn to the centre of gravity, multiplied by the distances along those lines to the centre. In general the fins are grouped in opposing pairs: right and left pectoral, right and left ventral, dorsal and anal, upper and lower lobes of the caudal fin. In forward locomotion not only must the thrusts of normally opposing pairs be balanced (opposite torques around the centre of gravity) but, as shown by Breder (1926), an anterior fin, such as the pectoral, may often combine its thrust with that from one of the posterior fins.

With reference to the median, transverse and horizontal planes of the body, the fins are disposed as follows:

(a) In the median plane: the dorsal, anal and caudal fins, exerting *transverse* pressures.

(b) In the transverse horizontal plane: the pectorals and pelvics of primitive sharks, and the caudal keels of scombroids, exerting more or less *vertical* pressures.

(c) In the vertical lateral planes: the pectorals of many acanthoopts, when extended, exerting *antero-posterior* pressures.

The moments of force of the fins upon the centre of gravity will of course be influenced by the form and angulation of the fins as follows:

(a) Fins are usually directed more or less backward and when deflected to one side or the other they tend rather to draw the body towards them than to push it away from them.

(b) Convex or spatulate fins afford a firm push against the water and require broad powerful muscles to operate them.

(c) Concave fins or those with prolonged tips can be swept over a wider arc with relatively less effort than spatulate fins; they enable one part of a fin to be widely removed from the other and thus to reach to a position of mechanical advantage for certain movements (Nichols, Breder).

(d) In short-based median fins the rudder and paddle function predominates; long based fins can be thrown into longitudinal undulations which also may contribute directly to forward or backward movements.

(e) In general a gentle convexity offers a favorable surface for water to flow away from, a concavity on the other hand may induce a suction effect (Breder), or if reduced to a thin edge may steady or stretch a fin membrane (Breder). A steep slope in a fore-and-aft direction is like a wedge with a very obtuse angle which would require a short, sudden and violent effort to push through the water; on the other hand a gentle posteriorly decurved slope, is favorable for slight efforts accumulated in a longer time.

The facts of comparative anatomy and palæontology are all in favor of the view that both median and paired fins were originally merely accessory organs of locomotion, projections of the body wall and skin placed at favorable points to deflect the forces generated by the primary locomotor organs which are the myomeres.

### 3. *Contrasting mechanisms of dolichosomatic and hypsisomatic forms*

The placement of the points of reference of the quadrilaterals, as well as the dimensions and proportions of the diameters and boundaries are obviously conditioned by the location of the fins; which in turn bears a definite relation to the particular ways in which each kind of fish moves. Thus predatory, pike-like fishes

have a low entering wedge and a posteriorly placed strong axis of lateral turning (running vertically through the dorsal and anal fins) which permits sudden lateral displacements of the head and fore-part of the body. Hence the apex and the gasterion are placed far back, the downward slope of the base of the dorsal fin is slight, and the vertical diameters are very small. The long body is thrown into eel-like undulations, the amplitude of which increases posteriorly (Breder). In this case forward locomotion results from the longitudinal summation of the contractions of a long series of myomeres. At the other extreme such deep-bodied forms as the pomacentrids and angel-fishes have a high entering wedge, requiring short and very powerful muscles to push it through the water. The powerful posterior axis of lateral turning, by reason of the shortness of the body, is far nearer to the principal fulcrum than is the case in long-bodied fishes. Hence the vertical diameters are relatively great, the pygidion is relatively near to the prosthion and the postero-ventral boundary forming the base of the dorsal fin slopes downward at a sharp angle.

#### 4. *List of principal Body-forms in fishes*

While the number of body forms and precise modes of locomotion in fishes is great even in the groups below the swarming teleosts, a few of the more central or conspicuous types are as follows:

(1) Galeoid: body fusiform, head depressed, body pivoted anteriorly on high stiff dorsals and well developed pectoral fins, posteriorly on ventrals second dorsal and anal fins; tail heterocercal.

(2) Batoid: body and head depressed, pectorals extended transversely and forming the chief organs of locomotion. Tail typically reduced, ultimately to a whip-like trailer.

(3) Palæoniscoid: body fusiform, tail heterocercal, other fins small, but covered with incipient lepidotrichia; body pivoted on single apical dorsal.

(4) Platysomoid: hypsisomatic derivative of the palæoniscoid type, with dorsal and anal elongate, opposed, on sloping postero-dorsal, and postero-ventral boundaries.

(5) Polyodontoid: a naked derivative of the Palæoniscoid type, with a spoon-bill rostrum.

(6) Acipenseroid: secondarily armored derivative of the palæoniscoid type, with the snout produced, the dorsal fin shifted

backward and the pectorals strengthened by a stout bony anterior ray.

(7) Semionotoid: primitive holostean ganoid, body compressed, mesosomatic, tail hemi-heterocercal.

(8) Lepidosteoid: a long bodied predatory derivative of the Semionotoid type, with posteriorly displaced axis of lateral turning (dorsal and anal).

(9) Pycnodontoid: a compressed hypsisomatic derivative of the semionotoid type. Small-mouthed nibbling and crushing fishes, somewhat resembling the Ehippidæ among the teleosts.

(10) Caturoid: a fusiform, predatory holostean ganoid type with large forked tail.

(11) Amioid: a long bodied holostean with elongate dorsal fin and spatulate hemi-heterocercal tail.

(12) Pholidophoroid: more or less clupeoid holosteans, the long-bodied ones possibly derived from a disciform type (Abel).

(13) Clupeoid: compressed fusiform mesosomatic isospondyls with abdominal ventrals and no spines on the fins; tail homocercal.

(14) Esocoid: Dolichosomatic predatory haplomi, with posteriorly displaced turning axis (dorsal and anal).

(15) Anguilloid: hyperdolichosomatic, with reduced fins.

(16) Berycoid: primitive acanthopt type: hypsisomatic (disciform), with ventrals thoracic and attached to cleithral arch.

(17) Serranoid: mesosomatic derivative of a primitive berycoid type, with elongate dorsal becoming differentiated into spinous and soft portions; all fins large and highly extensible.

Other teleost types will, it is planned be dealt with in a later paper.

The body-forms of fishes may be referred to the following descriptive series:

(1) depressed (euryomatic)

(2) fusiform (mesosomatic, dolichosomatic)

(3) anguilliform (hyperdolichosomatic, with reduced fins)

(4) disciform or compressed (hypsisomatic).

Or they may be classed as highly flexible, intermediate, loricate (most ostracoderms, arthrodires, plecostomine loricariids, triglids, *Hippocampus*) and rigid (e. g. *Lactophrys*). Such forms are evolved independently in different natural groups. On the other hand each of the body-forms listed in this paper, together with each

of the very numerous body forms among teleosts, is highly individualistic and represents a unique combination of body and fin-forms with special movements, for which no *exact* parallel can be found in any other natural group.

#### 5. *The starting point of the fish-like body-form*

In considering Barrell's hypothesis (1916) that the earliest chordates were elongate, eel-like forms that originated in fresh water rather than in the ocean, it should not be forgotten that among recent fishes only a few fresh water forms have succeeded in invading the ocean, while very many pelagic families have sent representatives into the estuaries and streams. But this in itself does not indicate which way the invasion took place in early Palæozoic times when certainly the fishes and presumably the stream-gradients and salinities were on the whole different from those of the present day. As to the evidence from palæichthyology it may well be true that most of the known Palæozoic and early Mesozoic fishes are found in epicontinental deposits and that some of the descendants of these fishes (as in the order Isospondyli) have succeeded in invading the ocean. It is also true that many primitive fishes of to-day, *e. g.*, the brook lamprey, all the ganoids, dipnoans, crossopterygii, many isospondyl teleosts, nearly all the Nemato-gnathi, many Haplomi and not a few primitive Acanthopterygii, live or breed in fresh water. But there are also many other primitive types of different grades that have survived in the ocean (*e. g.* sharks, *Amphioxus*, many isospondyls, Haplomi, Iniomi, and relatively primitive Acanthopterygii of many families), so that we are not dealing with one invasion and in one direction but with many, in either direction and at different times, each of which must be studied on its own merits in detail, before any far reaching generalization as to the first migration should be made.

As to the frequent assumption that the earliest fishes were elongate and eel-like, the evidence of palæontology as recognized by A. S. Woodward is decidedly adverse, since in all groups in which the palæontological history is known the earliest forms were more or less short-bodied and very unlike an eel. The Silurian Anaspida form an important exception.

The combined evidences of palæontology, morphology, embryology and taxonomy prove only that the primitive chordate was

orientated to head up stream but it does not indicate whether the current was of fresh or saline water.

The foregoing does not carry us very far toward the solution of the problem of the origin of the vertebrates. Even the primitive ostracoderm of Ordovician times was already, it seems, a typical chordate, with no generally accepted evidences of close relationship to any invertebrate phylum. Unless Patten's way of deriving the chordates from eurypteroid arachnids, with its difficult twistings and transpositions of organs should eventually be proved to be true, we are left with no known intermediate stages to connect the stem ostracoderm (nearest perhaps to the Anaspida) with a bottom-crawling coelenterate having incipient bilateral symmetry and mesoderm pouches from the archenteron. Nevertheless such a stage, already inferred by Masterman and others from the comparative embryology of the protochordates, seems to afford the most favorable starting point for the chordate locomotor apparatus. In either case it seems probable that the first chordates were by no means eel-like free-swimming forms but somewhat depressed and partly bottom-living forerunners of the anaspid ostracoderms.

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# ZOOLOGICA

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DEPARTMENT OF TROPICAL RESEARCH  
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### AN ANNOTATED LIST OF THE SYNENTOGNATHI

With remarks on their Development and Relationships

BY J. T. NICHOLS

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C. M. BREDER, JR.

*New York Aquarium*

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# AN ANNOTATED LIST OF THE SYNENTOGNATHI\*

## WITH REMARKS ON THEIR DEVELOPMENT AND RELATIONSHIPS

Collected by the *Arcturus*

BY J. T. NICHOLS AND C. M. BREDER, JR.

(Figs. 156-176 incl.)

The present paper is based on specimens of the order Synentognathi collected by the *S. S. Arcturus*, under the direction of William Beebe. Both Atlantic and Pacific forms are represented in the collections of that expedition (February to July, 1925).

We have laid emphasis on the larval and post larval development of the various species, partly because the material allowed of it, but chiefly because we believe that a study of the young stages will do much to clarify the relationships of the forms encompassed in this order. This has been our main objective and as a consequence we have written in as much of the indications of phylogeny as our studies of the specific ontogenies would permit. It should be added that material showing the changes between young and adult flying fishes is rare in collections, and more of it must be assembled before the group will be satisfactorily known.

### Family BELONIDAE

*Strongylura ardeola* (Cuvier and Valenciennes).

Specimens 280, 285, 320 mm. standard length (Atlantic), No. 5047.

This is a clearly recognizable species, synonymized with poorly described *ardeola* (Cuvier & Valenciennes) by Jordan & Evermann. Jordan (1919, Proc. U. S. Nat. Mus. LV, p. 397) synonymizes *ardeola* with *T. argalus* Le Sueur (1823, Journ. Acad. Phil., II, p. 125, fig.) which is, however, not our fish. *Belone depressa* Poey (1860) has priority over *Belone depressa* Gunther (1866). In our material, which we identify with *ardeola* (following Jordan and Evermann, 1896, not Jordan, 1919), the jaws are very long and slender, in the 280 mm. specimen the lower jaw extending 15 mm. beyond the tip of the upper. Lower jaw measured from eye, 3.6 times rest of head.

Close to *pterurus*, Osburn & Nichols, 1916, which differs in more posterior insertion of ventrals, nearer base of caudal than eye, versus equidistant between the two, and also has about 2 less rays in the anal.

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*Strongylura pterura* (Osburn and Nichols).

A specimen 293 mm. standard length (Pacific), No. 5724.

*Strongylura fodiator* (Jordan & Gilbert).

A specimen 710 mm. standard length from Cocos Id., No. 5840.

*Strongylura pacifica* (Steindachner).

A specimen 68 mm. standard length, No. 5184.

Snout 11.5 mm. (measured from front of eye), beyond which the lower jaw extends 18.5 mm. more. Compared to the standard length of the fish, the lower jaw (measured from front of eye) is half again as long as in *S. marina* of the same standard length, but the upper jaw (snout) is about the same as in that species. See Breder, 1926, Copeia No. 153, p. 123. Peduncle prominently depressed but with no evident keel at this size.

*Ablennes hians* (Cuvier & Valenciennes).

Atlantic—Station 22, 9 examples 48 to 143 mm. standard length, No. 5044a; 2 examples 165 to 141 mm. standard length. Pacific—A specimen 730 mm. standard length, No. 5629.

The following table indicates the comparative rates of growth of the upper and lower jaws and the sizes of our specimens.

Standard length (mm.)	Upper jaw (mm.)	Lower jaw (mm.)	Difference (mm.)	Percentage
730	—	—	—	—
165	39.75	49	10.75	81 +
143	31	34	3.00	91 +
141	33	40	7.00	82 +
100	—	—	—	—
80	—	34	—	—
68	12	—	—	—
65.5	13	—	—	—
63	12	22.5	10.50	53 +
62	10.5	—	—	—
56.5	10	20.5	10.50	48 +
48(?)	—	19	—	—

#### Family HEMIRAMPHIDAE

*Hemiramphus brasiliensis* (Linn.).

One from Bermuda 160 mm. standard length, No. 5000. Also another example from the Atlantic, 180 mm. standard length, No. 5045, and one from the Pacific 340 mm. standard length, No. 5349, which according to Gilbert and Starks, 1904, should be *H. saltator* Gilbert & Starks. However, the alleged differences these specimens display for the Atlantic and Pacific appear to be age characters. All three specimens fall in *saltator*, as defined by Meek and Hildebrand. Comparison of adequate material may show the Pacific form to be distinguishable as a race, but we are unable to separate it. The critical

measurements of our material are as follows, expressed in hundredths of standard length:

Measurement	Atlantic	Atlantic	Pacific
Standard length in mm.	160	180	330
Eye	.06 9/10	.06 3/10	.04 4/5
Pectoral length	.19	.19	.19
Dorsal height	.10 3/10	.08 4/5	.08 7/10
Dorsal to ventral insertion	.15	.16	.18
Postorbital part of head	.08 7/10	.10 1/2	.10 9/10
Depth	.12	.15	.16
Head	.24	.23	.23
Gill-rakers	28	27	27
Ventrals	midway base caudal & basal 4th of pect.	midway base caudal & axil pect.	midway base caudal & axil pect.
Scales	58	61	60

Gilbert & Starks give .18-.21 for the pectoral length of *H. saltator* and .16-.17 for *brasiliensis*, whereas all our examples have .19. The lower mandible differences we believe to be fortuitous. It is to be especially noted that Gilbert & Starks (1904) compare fishes of different size groups in their table. That is, their *H. saltator* range from 213 to 283 mm. and their *H. brasiliensis* range from 190 to 222. This fact seems to strengthen our opinion that the alleged differences are due to age.

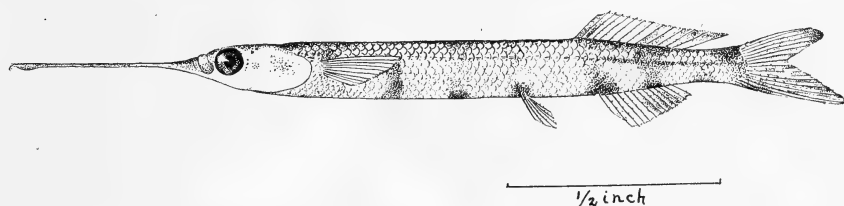


Fig. 156. Young *Hemiramphus* from the Pacific, of 50 mm. total length

We also have some juvenal fish of this species. Nos. 5184, 6215, 5102, 5248,—50 mm. to 13 mm. standard length. The largest may be described as follows: Sides flat, back convex, belly flat. Posterior dorsal rays elevated, black. Lower jaw extends beyond snout 20 mm., black. Ventrals and caudal dusky bordered with pale. Series of about 9 dark blotches on sides, 4 cross marks on belly.

#### *Hyporhamphus*, sp.

Specimens up to 35 mm. standard length, Pacific, No. 5248.

Juvenal specimens from the Atlantic, Nos. 5076 and 5072, and two from Bermuda, Feb. 16, 90 mm. standard length.

The material is too small to be significant in a discussion of the distinctness of the two or three nominal American species of this genus.

*Euleptorhamphus longirostris* (Cuvier).

One from Hood I., Galapagos, No. 5461. Also Nos. 5459, 5455, 5726, 5456,—370 mm. to 293 mm. standard length.

The example of 370 mm. has the lower jaw measuring 147 mm. from eye to tip.

The ventral of *Euleptorhamphus* is forked in a peculiar manner (superficially like the caudal of a small fish). A tendency to bilobed ventrals may be traced through the Hemiramphidae to the Exocoetidae. See fig. 168.

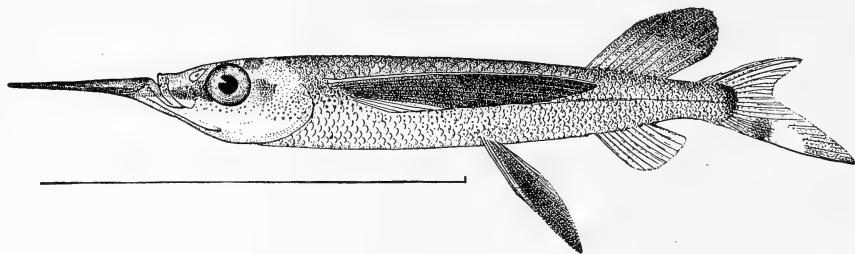


Fig. 157. *Fodiator acutus* (Cuvier and Valenciennes) of 34.5 mm. standard length

#### EXOCOETIDAE

*Fodiator acutus* (Cuvier and Valenciennes).

One of 34.5 mm. standard length, No. 5572.

This single small specimen differs from the existing descriptions of the species, based on larger examples in the greater length of the lower jaw. Snout to end of lower jaw 9 mm. Otherwise the specimen is much like the adults. See fig. 157.

Fowler, 1901 (Proc. Phila. Acad. Sci., p. 293, fig.), figures and bases the genus *Hemioxocoetus* which he places in the Hemiramphidae on a still smaller specimen 25 mm. in standard length, with an even longer 'beak,' at the same time calling attention to its resemblance to *Fodiator*. We have no hesitation in identifying our intermediate specimen with *Fodiator*, and very little hesitation in identifying it with *Hemioxocoetus* Fowler.

*Evolantia microptera* (Cuvier & Valenciennes).

Specimens numbered 5310, 5543, 5545, 5560, 5690a, 5743, 5953, 5962b, 6033b, 6049, 6059a, ranging from 155 mm. to 4 mm. standard length.

The smaller examples up to 58 mm. (or more) show a pronounced prolongation of the lower jaw. This becomes more pronounced with decrease in size reaching its maximum at about 17 mm. Below this it is less pronounced. The very small (4 mm.) specimens do not show more than a sharp point to the jaw. At 8 mm., specimens are intermediate between the condition of 17 mm. and 4 mm. See Figs. 158 and 159.

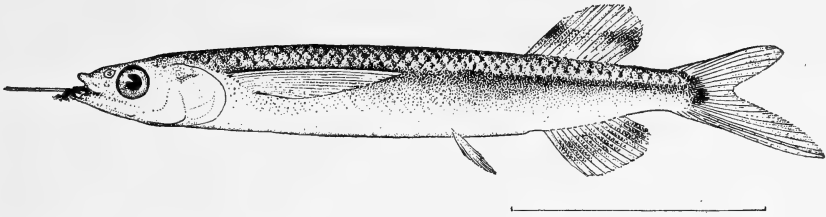


Fig. 158. Two stages of *Evolantia microptera* (Cuvier and Valenciennes), juv.

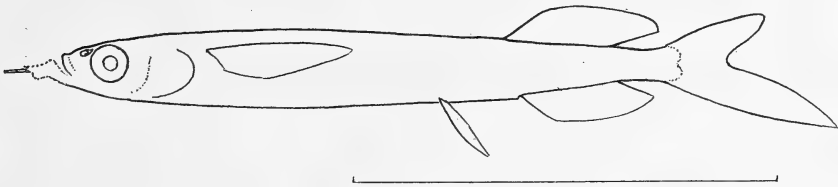


Fig. 159. Two stages of *Evolantia microptera* (Cuvier and Valenciennes), juv.

The temporary beak, consists of a pair of slender prolongations of the dentary, which seem to break through the skin as it approaches maximum length (the bones project from the skin in all our specimens), and later to break off normally and be lost in that way, while the loose skin heals to the chin.

*Parexocoetus mesogaster* (Bloch).

Two specimens from the Atlantic, 110–109 mm. standard length, No. 5044.

*Halocypselus evolans* (Linn.).<sup>1</sup>

Specimens from Cocos, 158 mm. standard length, No. 5768; from the Atlantic, 83 and 85 mm., No. 6461, and 97 mm. No. 5165. Also, one of 34 mm. No. 5187. Smaller specimens as follows: 5249, 5279, 5420, 5938, 5965, 6046, 6056, 6071, 6137.

This species is separable from *H. obtusirostris* when small in that the latter has a large simple barbel on the chin, while *H. evolans* lacks it.

The following characters while slight and sometimes overlapping, also help to separate the two species.

*evolans*

Anal origin—behind dorsal.  
Distance from snout to ventrals—  
equal to or greater than ventrals to  
last dorsal ray.

*obtusirostris*

In advance of dorsal.  
Less than ventrals to last dorsal ray.

<sup>1</sup> See Nichols 1922, Copeia, page 50; Jordan 1924, Copeia, p. 89.

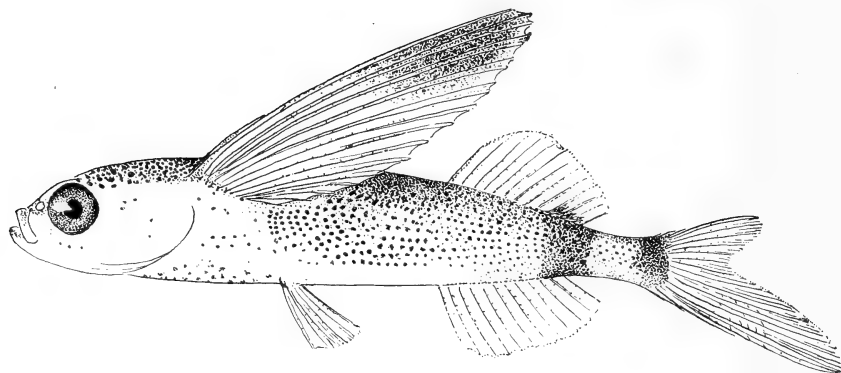
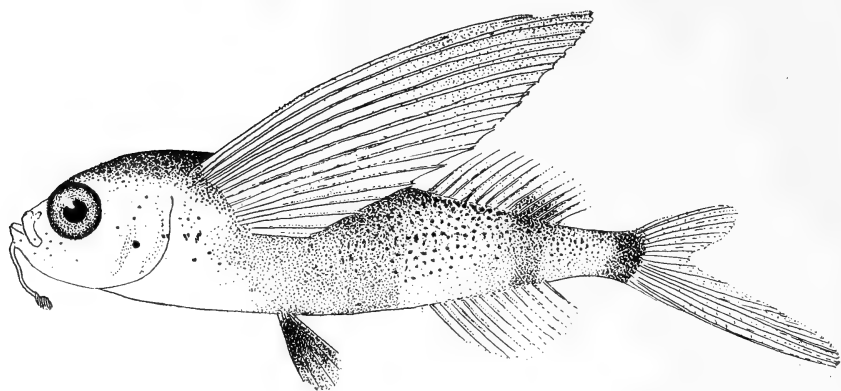


Fig. 160. *Halocypselus obtusirostris* (upper), *H. evolans* (lower) of comparable size.

*evolans* cont'd.

Scales, dorsal to lateral line— $6\frac{1}{2}$ .

Rarely 6 or 7.

Pectoral color—dark with a pale margin ( $2\frac{3}{4}$  to 4 inch fish).

*obtusirostris* cont'd.

$7\frac{1}{2}$  or 8.

Pale with a narrow dark margin.

*Halocypselus obtusirostris* (Günther).

Specimens with the following numbers: 5166, 5397, 5542, 5710, 5938, 5965, 6137, 6400, 6419—the largest 57 mm. standard length.

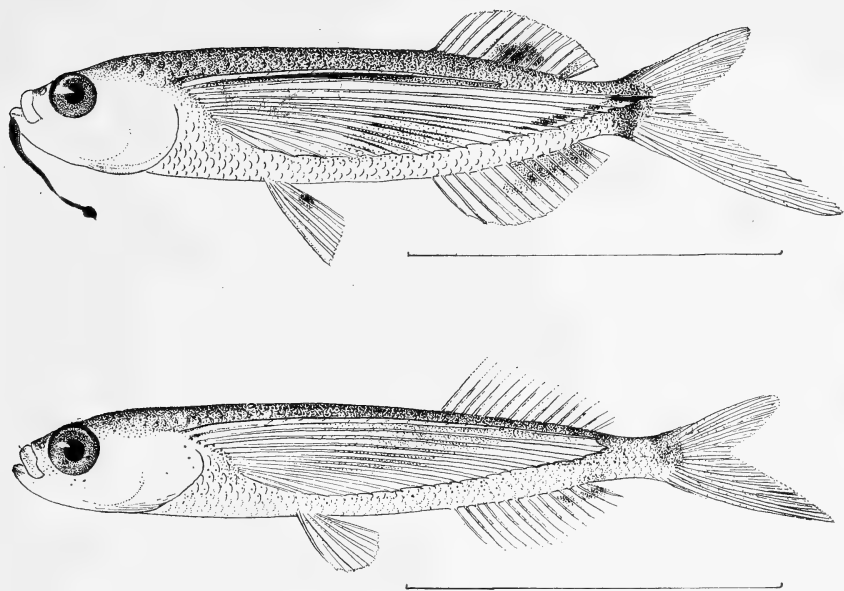


Fig. 161. *Halocypselus obtusirostris* (upper), *H. evolans* (lower) of comparable size.

*Exonautes rondeletii* (C. & V.).

One without data, 62 mm. standard length.

Juvenals, Nos. 5157, 5321, 5570, 5572, 5887, 6040, 6415.

We refer to this species a number of small flying fish 16 mm. and less in standard length with robust bodies and blackish paired fins.

*Exonautes marginatus*, sp. nov.

A number of specimens, the largest 40–50 mm. standard length, Nos. 5164, 5185, 6072.

We have some hesitation in giving a new name to this material. It may possibly be the young of *E. affinis* or *speculiger*, but seems not to be such. The smallest specimens have pectorals pale with narrow dark borders. At a somewhat larger size pectorals are streaked with dark. There are two broad dark broken bands across the breast, the anterior one at base of pectorals.

*Description of type:* No. 9234, American Museum of Natural History, current rip, Lat.  $2^{\circ} 36' - 2^{\circ} 8' N$ . Long.  $85^{\circ} 1' - 86^{\circ} 31' W.$ , collected by Arcturus Expedition.

Length to base of caudal 45 mm. (59 mm. to tip lower caudal lobe). Depth in length, 6.7; head 4.3; pectoral 1.35; ventrals 2.3. Eye in head 2.3; snout 4; interorbital 3; maxillary 3.2; maximum width of body (at base of pectorals 1.3);

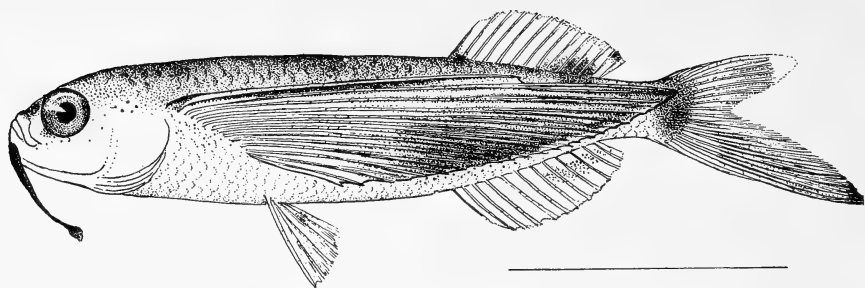


Fig. 162. *Halocypselus obtusirostris* of 57 mm. standard length.

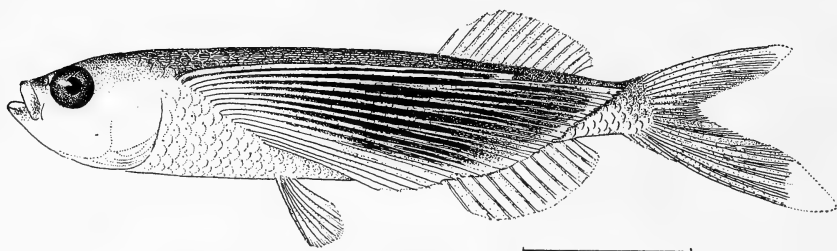


Fig. 163. *Halocypselus evolans* of 97 mm. standard length.

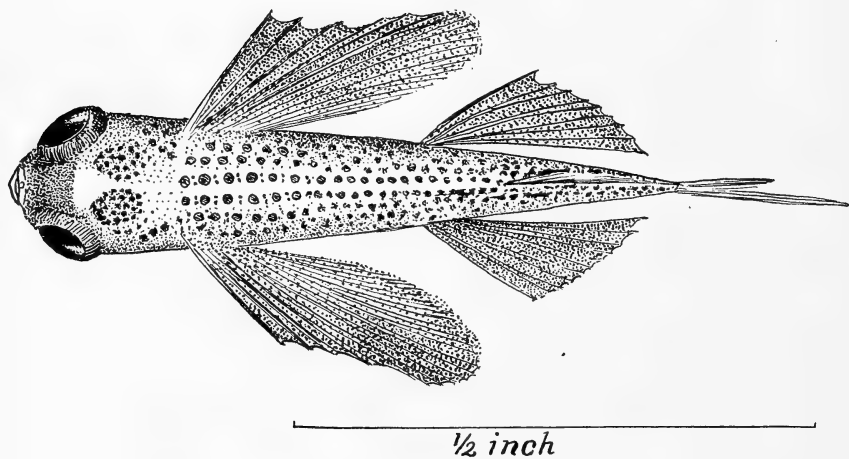


Fig. 164. *Exonautes rondeletii* of 16 mm. standard length.

length of peduncle 1.5; its depth 2.9; longest dorsal ray 1.5; longest anal ray 1.8; lower caudal lobe 0.7.

Dorsal 11; anal 12. Scales about 43.

No barbels. Maxillary nearly vertical, not reaching orbit; orbital rim slightly raised. Dorsal origin at  $\frac{2}{3}$  the distance from margin of opercle to caudal base, slightly behind that of anal; origin of ventrals about equidistant from base of caudal and edge of preopercle. Depressed pectorals reach to middle of peduncle, ventrals to base of caudal. First pectoral ray not quite  $\frac{2}{3}$  length of second, second slightly more than  $\frac{1}{2}$  the third, third simple, slightly shorter than fourth (divided) which is the longest.

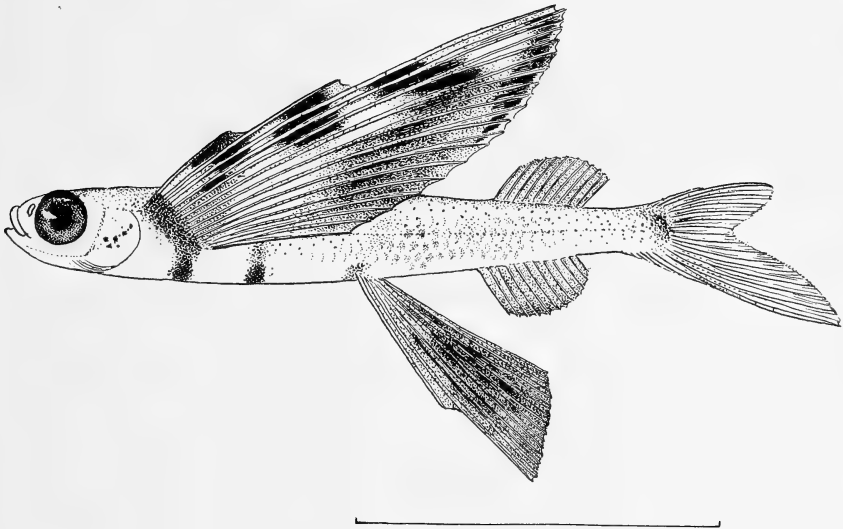


Fig. 165. *Exonautes marginatus*, type, 45 mm. standard length.

*Cypselurus furcatus* (Mitch.).

Two specimens from the Atlantic of 130 to 140 mm. standard length, and juvenals. Nos. 6453, 6461.

Large examples show the wings striped differently from the figure in Fowler, 1906, Repts. & Amphibs, N. J.

*Cypselurus nigricans* (Bennett).<sup>2</sup>

Three specimens 30 to 50 mm. standard length, Pacific, No. 5183. Dorsal, high black; wing stripe not bold. Very small specimens apparently this species, Nos. 5124, 5321, 5329, 5708, 5962, 6410.

<sup>2</sup> Nichols, 1924, Zoologica, V, p. 63.



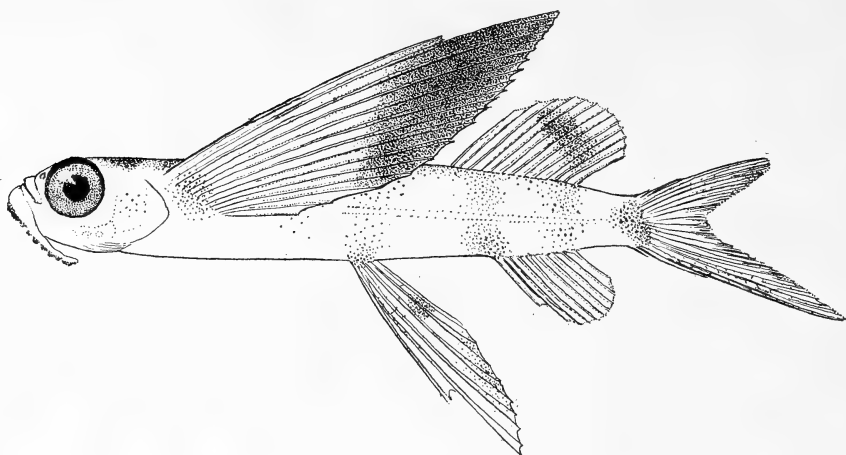


Fig. 166. *Cypselurus bicolor* (Cuvier and Valenciennes) of 33 mm. standard length.

*Cypselurus bicolor* (Cuvier and Valenciennes).

A small flying fish from the Pacific, 36 mm. standard length, No. 5960 is provisionally placed with this species.

Barbels present. More slender than is similar sized *C. nigricans*; caudal lobe larger. Pectoral pale with abrupt black terminal part. Second pectoral ray longest, versus third as in *C. nigricans* of same size. This ray is simple, apparently becoming split in these fishes as they grow larger. There is a remote chance that this fish may develop into the common *C. bahiensis*.

*Cypselurus bahiensis* (Ranzani).

A number of specimens mostly from Gardners Bay, Hood I., 300–320 mm. standard length, Nos. 5350, 5441, 5458, 5463, 5464, 5465, 5469.

*Cypselurus callopterus* (Günther).

Specimens 229 to 273 mm. standard length, mostly from Gardners Bay, Hood I., —Nos. 5462, 5466, 5467.

*Cypselurus monroei*, sp. nov.

In comparing *Arcturus* material with flying fishes in the American Museum of Natural History from other sources, we find a small specimen from Florida so unlike any adult known to us that we venture to describe it as new. The type, No. 8678 Am. Mus. Nat. Hist., Coconut Grove, Florida, Jan. 22, 1921, collected by Comm. R. M. Monroe, is 48 mm. in length to base of caudal. Depth in length, 6; head, 4.6; pectoral, 1.7; ventral, 2.5; Eye in head, 2.7;



Fig. 167. *Cypselurus monroei*, type, 48 mm. standard length.

snout, 3.8; interorbital, 5.4; maxillary, 4; width of head, 2.1; greatest width of body, 2; barbels, 0.5; depth of peduncle, 2.7; lower caudal lobe, 0.7; longest dorsal ray, 1.2; anal ray, 1.5.

Dorsal rays,  $13\frac{1}{2}$ ; anal, 9. Scales about 40 or 45.

Body subelliptical in cross-section, very like that of *Parexocoetus mesogaster*; head narrowed forward. Ventrals inserted midway between edge of preopercle and base of caudal; dorsal inserted at  $\frac{2}{3}$  the distance from anterior margin of pupil to caudal base; anal well behind dorsal. Pectorals reach beyond middle of dorsal; ventrals to middle of peduncle. Two long simple fleshy tapering mandibular barbels, separate to base, each elliptical in cross section, pale colored with a dark fluted membrane at either side. Color in alcohol,—body palish; pectorals dusky, blacker posteriorly, base and inner margin pale; ventrals nearly uniformly dusky; dorsal dusky; anal pale, slightly dusky centro-marginally; caudal grayish.

#### DIFFERENTIATION OF VENTRAL FINS

The ventral fins of the synentognathi show some interesting differentiations which fit in readily with the phylogenetic tree here based on other characters. In the primitive Belonidae the ventrals are quite "normal," that is, of an outline common to most generalized fishes (Fig. 168, 1). In the derived Hemirhamphidae these fins are

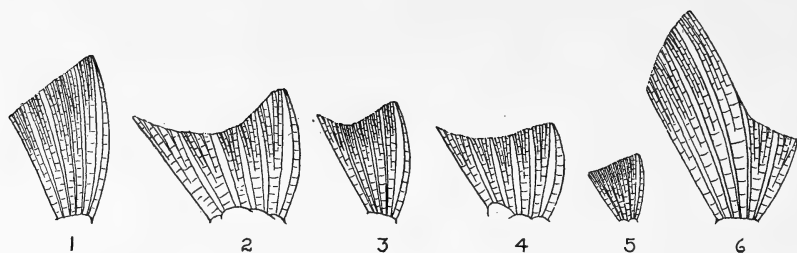


Fig. 168. Syntognath ventrals (right side viewed from below). 1. *Strongylura ardeola*; 2. *Hemiramphus brasiliensis*; 3. *Euleptorhamphus longirostris*; 4. *Evolantia microptera*; 5. *Halocypselus evolans*; 6. *Cypselurus callopterus*.

concave instead of obliquely truncate, and the inner ray is considerably produced. In *Hemiramphus* itself, this condition is most pronounced (Fig. 168, 2), whereas in *Euleptorhamphus*, in keeping with the idea that it has been "hurried out of the Belonid group," the concavity is less pronounced and the inner ray is less produced (Fig. 168, 3). Also, the length of the fin is greater in proportion to the breadth as in the Belonidae and not shortened as much as in *Hemiramphus*. In the "two-winged" flying fishes *Evolantia* and *Halocypselus* the fin is very like that of *Hemiramphus*, the chief difference in *Evolantia* being a flattening out of the concavity and a very slight lengthening of the fin (Fig. 168, 4). Going on to *Halocypselus*, the margin is practically straight again and the fin longer (Fig. 168, 5). In the "four-winged" group where these fins are used definitely as planes, there has been a great lengthening of the third ray as in *Cypselurus* (Fig. 168, 6). *Fodiator* is quite intermediate between the ventral fin condition of *Hemiramphus* and *Cypselurus*. The other genera of the "four-winged" group are essentially similar to the one figured and other genera in each family not figured or mentioned above are similar to their nearest allies which are figured.

The significance of these transformations is not clear, although it is evident that in the "four-winged" group of flying-fish the larger surface enables the ventrals to function to greater effect as planes.

#### CONCERNING THE PRESENCE OF GILL-RAKERS

Whereas we consider the Belonidae as basal in the Syntognath group, they have certain specialized characters not shared by its



Fig. 169. *Ablennes hians*. First gill arch of a 52 mm. example (standard length) showing vestigial gill rakers still present.

other members. For instance, all but *Belone*, which may be looked upon as the most primitive member of the family, lack gill-rakers. It is therefore interesting to find, in examining young *Ablennes hians* not over 52 mm. long that distinct traces of gill-rakers are present (Fig. 169). At a slightly larger size these disappear, and we believe their presence to be a juvenal retention of a less specialized character, perhaps correlated with juvenal feeding habits. On either side of each vestigial gill-raker a tiny spine is located the function of which we do not attempt to interpret. Without knowledge of how generally vestigial gill-rakers are present in young Belonidae, our hypothesis that Hemiramphidae are fixed larval Belonids in no way precludes their origin from forms which have lost gill-rakers in the adult.

#### SCHLESINGER ON THE SCOMBERESOCIDAE

The unquestioned relationship, diversity of forms, and seemingly tangled phylogenetic lines within the Synentognathi, are reflected in the considerable discussion of this group in the literature. The only paper to which we wish particularly to refer is by Schlesinger, 1909, "Zur Phylogenie und Ethologie der Scombresociden."<sup>3</sup> Scomberesocidae is here used in a broad sense for the whole group. The paper is a comprehensive one touching on various aberrant and exotic genera which we have not seen, and generalizing from what seems to us a rather imperfect knowledge of the habits of various forms, certainly of those with which we are familiar. On the other hand, considerable sound data is brought forward and well presented for recognition of two main divisions of the group, Microsquamati (needle fishes, etc.) and Macrosquamati (halfbeaks and flying fishes) which we consider as subordinal. Phylogenetically the cleavage between Belonidae and Hemiramphidae would seem to be a deep one. From which series the specialized genera *Euleptorhamphus* and *Scomberesox* are derived and which they parallel is

<sup>3</sup> Verh. Zool.-Bot. Ges. Wien, LIX, p. 302-339.

open to question, or perhaps they spring from an intermediate series, now mainly lost.

#### FLYING-FISH EVOLUTION

In constructing an hypothetical phylogeny of the needlefish-flying fish group, a sound initial step is to select the basic or most primitive member. This would seem to be the needlefish, an elongate predaceous form with toothed jaws, and the leaping habit. The needlefish tail may be either homocercal or reversely heterocercal, which later character has persisted throughout its derivatives, *Hemirhamphus* and the flying fishes, which have also the leaping habit, seized on and carried to an extreme, correlated with specialized fin (wing) structure in the flying fishes.

The half-beak tendency is foreshadowed in the young of the needlefishes with a shorter upper jaw. This might be brought forward as evidence of the half-beaks' being ancestral to the needlefishes, but such knowledge as we have of evolutionary drift in marine surface fishes leads us to interpret it otherwise. Larval fish forms are not as a rule parallel to the phylogeny of the adult but specialized adaptations (correlated with different feeding habits, etc.) to the different environment which the young must meet due to its small size. Instances are not lacking where such specialized larval forms become established as the adult form, making an evolutionary step upward, and it is just this which seems to have taken place in the transition from needlefish to half-beak.

An apparently superficial character frequent with larval needlefishes, but one which should be given weight due to its persistence in other members of the group, is elevation of the vertical fins, especially of the dorsal, which at the same time is usually dark colored. In small fishes there frequently seems to be correlation between such fin development, which has no very obvious advantage and would tend to impede the progress of the bearer through the water, correlated with the habit of drifting in ocean currents. It is interesting to find an appreciable manifestation of this tendency to an enlarged dorsal in the young of *Hemirhamphus*, and it is a persistent character in certain primitive flying fishes, *Fodiator*, *Parexocoetus*. It is not unreasonable to suppose that it is in these cases perhaps an indication of phylogenetic affinity. There is another point that should be referred to in considering the develop-

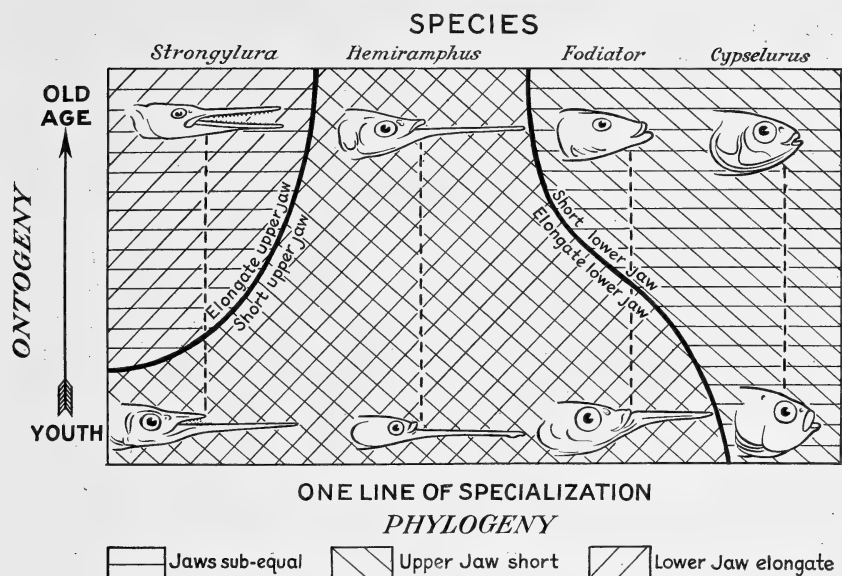


Fig. 170. Diagram of half-beak condition in phylogeny and ontogeny.

ment of the halfbeaks from needlefishes: the halfbeaks may not be strictly monophylatic, but may arise from approximate parallel lines with closely related ancestors. It is conceivable that *Hemiramphus* arose from those needlefish with lunate caudals and enlarged dorsals in the young; *Hyporhamphus* from other species.

At any rate it is from the *Hemiramphus* type of half-beak that the flying fishes would have developed, and in this connection it is interesting that very small *Hemiramphus* have a superficial character in common with various flying fishes of equally small size in the peculiar bands of dark color which cross the ventral surface.

Leaving the half-beaks we come to two primitive flying fishes quite unlike in character and will first mention *Fodiator* a rather short winged species with elevated dorsal, projecting chin and a short body with an elliptical cross-section. The present collection contains an individual which seems to be smaller than any previously figured as such, and this has the chin prolonged into a very respectable half-beak which we consider an ontogenous character reflecting flying fish phylogeny. Notice the difference in interpretation of the same half-beak condition in young flying fishes and young needle-

fishes, a difference which seems to be justified by the facts of the case. Not only are the toothed needle-fishes a priori more primitive and the winged flying fishes a priori more specialized than the half-beaks, but whereas the half-beak condition is peculiarly adapted to the feeding habits of very small fishes, flight is a character appropriate only to the adult as it is more or less dependent on weight of body and rigidity of wing which are functions of absolute size. Attention may be called to the—we think—somewhat unusual concept corollary to our accepted interpretation of the half-beak condition in young needlefish and flying fish.—It is, namely, that this character has lasted through different fish forms in the course of evolution, only part of the time as an adult character.

The most interesting material in the Arcturus collection for its bearing on the phylogeny of flying fishes is probably a series of young of another quite dissimilar primitive form, namely *Evolantia*, with elongate compressed body, small ventrals, and pectoral fins (or wings) comparatively little strengthened or enlarged. Though as fry *Evolantia* is without such, a little later it develops a fragile temporary beak on the lower jaw, which seems to be regularly lost at an early age by the enclosing fleshy skin breaking away from two slender supporting rods, the rods then breaking off and the skin being reduced leaving only a black spot on the chin. Such skin of a vestigial half beak furnishes us with a possible homology whereto to pin the peculiar barbels which occur as larval characters on the chins of this or that species of flying-fish, certainly with no obvious adaptive correlation. The pectorals of *Evolantia* increase in relative size with the growth of the fish. This form seems to stand rather close to the line of evolution from half-beak to flying-fish, a line which again was very likely polyphylatic. The affinities of *Evolantia* are perhaps with the typical flying fish *Halocypselus*, while those of *Fodiator* are more with *Parexocoetus*. *Fodiator* is already decidedly short bodied, one reason for looking upon it as rather aside from the main half-beak to flying fish trend which involves shortening of the body.

The singular form *Euleptorhamphus*, with half-beak condition at the apex of its development, combined with decidedly elongate and compressed body, must be a collateral specialization. We are unable to assign to it any significant position in the evolution of the group, though we can conceive of a not illogical sounding hypothesis

which would make of it a common ancestor and violate a surprisingly large number of seemingly sound concepts as to the nature of fish life and evolution. Perhaps the most satisfactory interpretation of this aberrant fish is that it was hurried out of the Belonidae by the same trends and forces which have controlled the general evolution of its group, too rapidly to differentiate on the basis of, or to correlate the characters involved.

Another aberrant form, *Scomberesox*, with half-beak young, may be looked upon as a throwback from the half-beaks towards needle-fish ancestors, but we prefer to interpret it as a relic from near the line of differentiation between these two families, on which have been superimposed certain specialized characters peculiar to itself.

#### SYNENTOGNATH RELATIONSHIPS

A phylogenetic tree of the Synentognathi based on our studies is shown in Figure 171. It is nearly self explanatory and the following notes are consequently brief.

#### MICROSQUAMATI

As understood by Schlesinger the most trenchant division of the order separates the large scaled forms from the small. Thus we have the families Belonidae and Scomberesocidae below the transverse line separating these divisions.

##### *Belonidae*

This family is certainly the most primitive of the group and although the others have come up through it, its separation as such from the main "trunk" has been early. Of the Belonidae, *Belone* with its retention of gill-rakers certainly is closest to the base of the needle-fishes' line of ascent. After the gill-rakers were lost we have another early split sending off the compressed and more specialized *Ablennes*. Moving on to *Strongylura* we have its fresh-water specialization *Potamorhaphis* with convex caudal, as an offshoot.

##### *Scomberesocidae*

This family has clearly arisen within the Belonidae, probably at some place close to where the modern Belonids separated from the stem leading to the Macrosquamati. Differentiation within it is simple and clear, *Cololabis* being a recognizable fixed larva of *Scomberesox*.



## MACROSQUAMATI

Treating the large scaled forms, there is one especial note to be made regarding *Euleptorhamphus* which we show as arising at some place between the Belonidae and Hemiramphidae (also at the line of differentiation between the Micro- and Macrosquamati) and following a line of its own within the Hemiramphidae. This, of course, makes the Hemiramphidae polyphyletic, and doubtless some students on such a basis would erect a new family for it, which actually would not be altogether unwarranted. However, we feel that it is better to leave it within the family on account of the hypothetical nature of such inferred relationships. It is also to be noted that of the Macrosquamati *Euleptorhamphus* has probably the smallest scales, which, with the other primitive characters it possesses, despite its specializations, is our reason for placing it adjacent to the Microsquamati line.

*Hemiramphidae*

The stem leading to *Euleptorhamphus* is discussed above. Regarding the main stem, although considerably divided, we do not feel that it is difficult to trace. *Hyporhamphus* is clearly near the base of this line of specialization possessing a simple air bladder. *Hemiramphus* like its allies variously retains primitive characters and gains others of a highly specialized nature. In the group that has taken to fresh-water and developed a convex caudal (analogous to *Potamorhaphis* among the Belonidae) we have *Hemirhamphodon* still bearing teeth on its long unapposed lower jaw as the most primitive. *Dermogenys* on the other hand has developed a curiously modified anal, the possible use of which we do not know, but along with it as a still further development we have the viviparous *Zenarchopterus* in which the male anal is an intromittent organ.

Along another line there are *Chriodorus* and *Arrhamphus* which have the beak reduced. In the former it is so far reduced as to give the fish an appearance not unlike an Atherinid.

*Exocoetidae*

It is clear that the flying fishes arose from some form more or less intermediate between *Hyporhamphus* and *Hemiramphus*. They early split into two types leading to the "two-winged" and "four-winged" species respectively. At the base of the latter stem we have

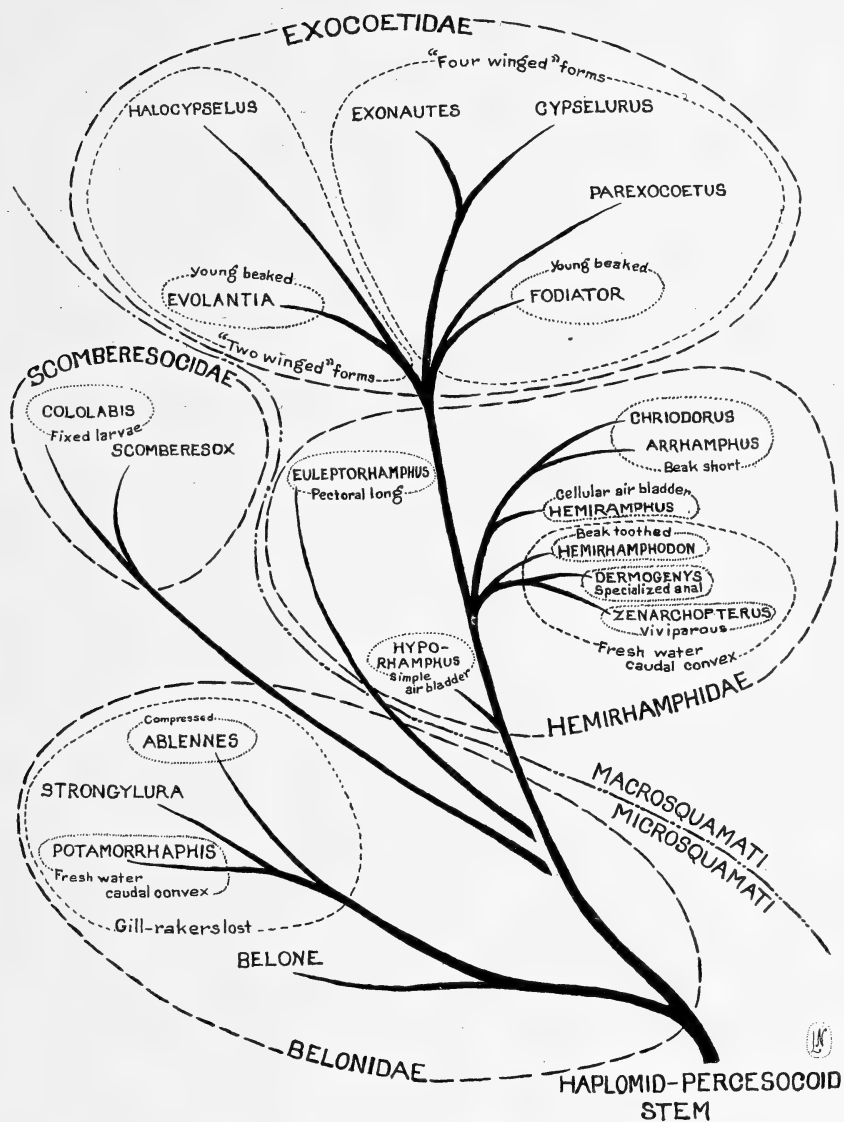


Fig. 171. Tentative lines of Synentognath evolution.

*Fodiator* which has a well developed "half-beak" as a larval character and very stubby wings. Comparatively closely related to it is *Parexocoetus* which has lost the beak of the young and developed larger wings but resembles *Fodiator* in having a body elliptical in cross section and a very high dorsal. From near where these two separate springs the stem leading to the highest development of aerial locomotion in fishes, *Exonantes* and *Cypselurus*. These two genera, while taxonomically distinct, are functionally very similar as regards powers of flight.

Although the "two-winged" flying fish are not as highly differentiated *inter se* they show a rather parallel evolution. Near the base we have *Evolantia* with short wings and a juvenal beak.

## SPECIMEN NUMBERS CITED, WITH LOCALITIES.

*Atlantic*

5000	Bermuda
5044	17° 56' N. 63° 12' W.
5044a	17° 56' N. 63° 12' W.
5045	17° 56' N. 63° 12' W.
5047	17° 56' N. 63° 12' W.
5072	Limon Bay, Colon, C. Z.
5076	Limon Bay, Colon, C. Z.
6453	30° 00' N. 60° 00' W.
6461	30° 00' N. 60° 00' W.

*Pacific*

5102	5° 03' N. 81° 08' W.
5124	3° 42' N. 83° 03' W.
5157	2° 36'-2° 08' N. 85° 01'-86° 31' W.
5164	2° 36'-2° 08' N. 85° 01'-86° 31' W.
5165	2° 36'-2° 08' N. 85° 01'-86° 31' W.
5166	2° 36'-2° 08' N. 85° 01'-86° 31' W.
5183	2° 36'-2° 08' N. 85° 01'-86° 31' W.
5184	2° 36'-2° 08' N. 85° 01'-86° 31' W.
5185	2° 36'-2° 08' N. 85° 01'-86° 31' W.
5187	2° 36'-2° 08' N. 85° 01'-86° 31' W.
5248	0° 19' N. 89° 57' W.
5249	0° 19' N. 89° 57' W.
5279	0° 05' S. 91° 11' W.
5310	0° 14' N. 91° 18' W.
5321	0° 31' N. 91° 00' W.
5329	0° 31' N. 91° 00' W.
5349	0° 19' N. 89° 57' W.
5350	0° 19' N. 89° 57' W.

5397	2° 00' S.	89° 30' W.
5420	2° 00' S.	89° 48' W.
5441	1° 22' S.	89° 39' W.
5455	1° 22' S.	89° 39' W.
5456	1° 22' S.	89° 39' W.
5458	1° 22' S.	89° 39' W.
5459	1° 22' S.	89° 39' W.
5461	1° 22' S.	89° 39' W.
5462	1° 22' S.	89° 39' W.
5463	1° 22' S.	89° 39' W.
5464	1° 22' S.	89° 39' W.
5465	1° 22' S.	89° 39' W.
5466	1° 22' S.	89° 39' W.
5467	1° 22' S.	89° 39' W.
5469	1° 22' S.	89° 39' W.
5542	0° 22' N.	88° 11' W.
5543	3° 52' N.	86° 43' W.
5545	3° 52' N.	86° 43' W.
5560	4° 56' N.	84° 35' W.
5570	3° 52' N.	86° 43' W.
5572	6° 16' N.	80° 48' W.
5629	Panama	
5690a	6° 27' N.	86° 54' W.
5708	6° 27' N.	86° 54' W.
5710	6° 30' N.	83° 33' W.
5724	Cocos	
5726	Cocos	
5743	Cocos	
5768	Cocos	
5814	Cocos	
5840	Cocos	
5887	4° 50' N.	87° 00' W.
5938	4° 50' N.	87° 00' W.
5953	4° 50' N.	87° 00' W.
5960	4° 50' N.	87° 00' W.
5962	4° 50' N.	87° 00' W.
5962b	4° 50' N.	87° 00' W.
5965	4° 50' N.	87° 00' W.
6033b	4° 50' N.	87° 00' W.
6040	4° 50' N.	87° 00' W.
6046	4° 50' N.	87° 00' W.
6049	4° 50' N.	87° 00' W.
6056	4° 50' N.	87° 00' W.
6059a	4° 50' N.	87° 00' W.
6071	4° 50' N.	87° 00' W.
6072	4° 50' N.	87° 00' W.
6137	2° 12' N.	89° 01' W.

6216	0° 16' N.	91° 23' W.
6400	0° 11' N.	91° 21' W.
6410	0° 17' S.	91° 34' W.
6415	4° 50' N.	87° 00' W.
6419	5° 04' N.	85° 04' W.



Fig. 172. Two-winged flying-fish (*Halocypselus evolans*) of 80 mm, standard length.  
From 'Natural History'. Drawing in colors. By Helen D. Tee-Van.

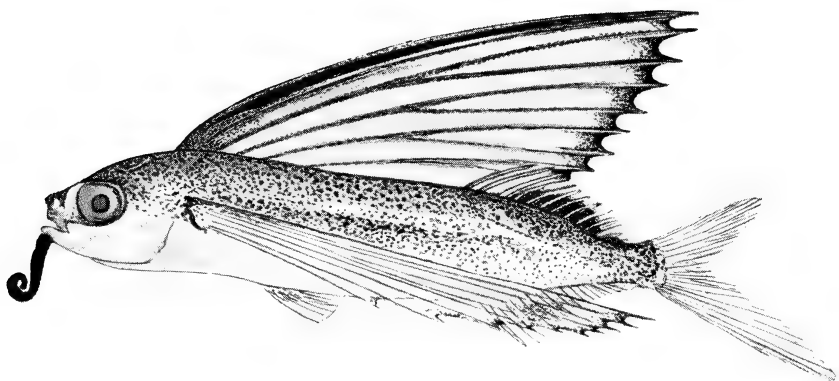


Fig. 173. *Halocypselus obtusirostris*.  
Drawing in colors. By Isabel Cooper.

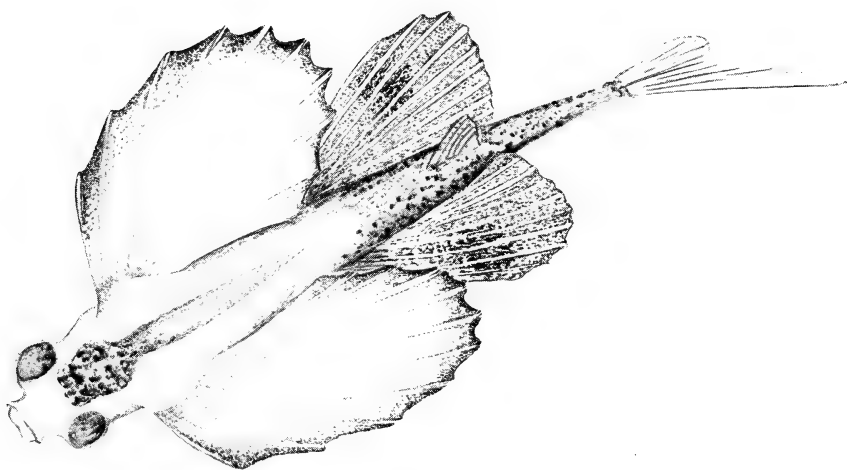


Fig. 174. *Exonautes marginatus* (Field No. 5148)  
Drawing in colors. By Isabel Cooper.



Fig. 175. Four-winged flying-fish (*Cypselurus furcatus*) of 160 mm. standard length.  
From 'Natural History'. Drawing in colors. By Helen D. Tee-Van.





Fig. 176. Young *Cypselurus furcatus* 65 mm. standard length.  
From: N. Y. Zoological Society Bulletin and Galapagos World's End.  
Drawing in colors. By Helen D. Tee-Van.

# ZOOLOGICA

## SCIENTIFIC CONTRIBUTIONS OF THE NEW YORK ZOOLOGICAL SOCIETY

DEPARTMENT OF TROPICAL RESEARCH  
ARCTURUS OCEANOGRAPHIC EXPEDITION

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Department of Tropical Research Contribution Number 297

### POLYCHAETOUS ANNELIDS FROM THE ARCTURUS OCEANOGRAPHIC EXPEDITION

BY AARON L. TREADWELL

*Vassar College*

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# POLYCHAETOUS ANNELIDS\*

FROM THE ARCTURUS OCEANOGRAPHIC EXPEDITION.

BY AARON L. TREADWELL.

*Vassar College.*

(Figs. 177-179 incl.)

The polychaetous annelids collected by the Arcturus Expedition were by the courtesy of Director Beebe, submitted to me for examination and the following is my report. One new genus and sixteen new species are represented in the collection. A tabulated list of the families follows:

Family	Old species	New genus	New species
Amphinomidae	6	—	—
Aphroditidae	1	—	—
Polynoidae	2	—	5
Alciopidae	2	—	1
Tomopteridae	—	—	2
Syllidae	5	—	—
Nephtydidæ	1	—	—
Chrysopetalidae	1	—	—
Phyllodocidae	4	—	1
Nereidae	2	—	2
Hesionidae	1	—	—
Glyceridae	2	—	—
Leodiciidae	16	—	1
Ariciidae	1	—	—
Spionidae	—	—	1
Flabelligeridae	—	—	2
Maldanidae	fragments		
Sabellariidae	1	—	—
Opheliidae	—	1	1
Terebellidae	2	—	—
Sabellidae	1	—	—
Serpulidae	1	—	—

\* Contribution, New York Zoological Society Department of Tropical Research, No. 295.

## Family AMPHINOMIDAE Kinberg.

*Eurythoe complanata* Pallas.

*Aphrodita complanata* (Pallas) 1776, p. 109, pl. 8, fig. 1926.

*Eurythoe pacifica* Kinberg, 1857, p. 14.

Collected at 17° 39' N., 63° 16' W., in 100 fathoms on Saba Bank; nine specimens; 0° 19' N., 89° 57' W., at Tower Island, Galapagos, one specimen; 0° 16' S., 91° 23' W., one specimen; 1° 22' S., 89° 39' W., at Hood Island, four specimens.

*Hermodice carunculata* Kinberg.

*Hermodice carunculata* Kinberg, 1857, p. 13.

Only three specimens, two of them very small, occur in the collection. The large one and one of the small ones, were taken at 17° 39' N., 63° 16' W.; while the other small one is recorded as taken one minute farther west. It seems possible that this distinction in locality may be an error. Kinberg's description of this species is very meagre, better ones occurring in McIntosh, (1885, pp. 24 to 27, pl. 5, p. 3A, figs. 1 to 4, and in Ehlers (1887), pp. 27 to 29). It seems probable that dorsal transverse intersegmental dark lines occur in the young, but disappear as the animal grows older.

*Amphinome* Brugiere.*Amphinome pallasi* Quatrefages.

*Amphinome pallasi* Quatrefages 1865, T. I, pp. 394, 395.

Collected at 2° 26' N., 85° 32' W., fourteen specimens.

*Chloeia* Savigny.*Chloeia euglochis* Ehlers.

*Chloeia euglochis* Ehlers, 1887, pp. 18 to 24, pl. 1, figs. 1 and 2; pl. 2, figs. 1 to 8, pl. 3, figs. 1 to 4.

Collected at 5° 32' N., 86° 59' W., at Cocos Island, two specimens.

*Notopygos* Grube.*Notopygos crinita* Grube.

*Notopygos crinita* Grube, 1855, p. 93.

Ehlers 1887, pp. 24 to 26, pl. 1, fig. 3, pl. 3, figs. 5, 6, 7.

Collected at 5° 32' N., 86° 59' W., Cocos Island, one specimen; 17° 39' N., 63° 17' W., in 100 fathoms, two small specimens. These have only fourteen somites and are unusually small but apparently are immature specimens of this species.

*Hipponoe* Aud. et M. Ed.*Hipponoe gaudichaudi* Aud. et M. Ed.

*Hipponoe gaudichaudi*, Audouin et Milne Edwards, 1834, pp. 128 and 129, pl. 2B, figs. 10, 10bis.

McIntosh, 1885, p. 30 to 33, pl. 1, fig. 5, pl. 4, fig. 3, pl. 3A, figs. 13 to 17.

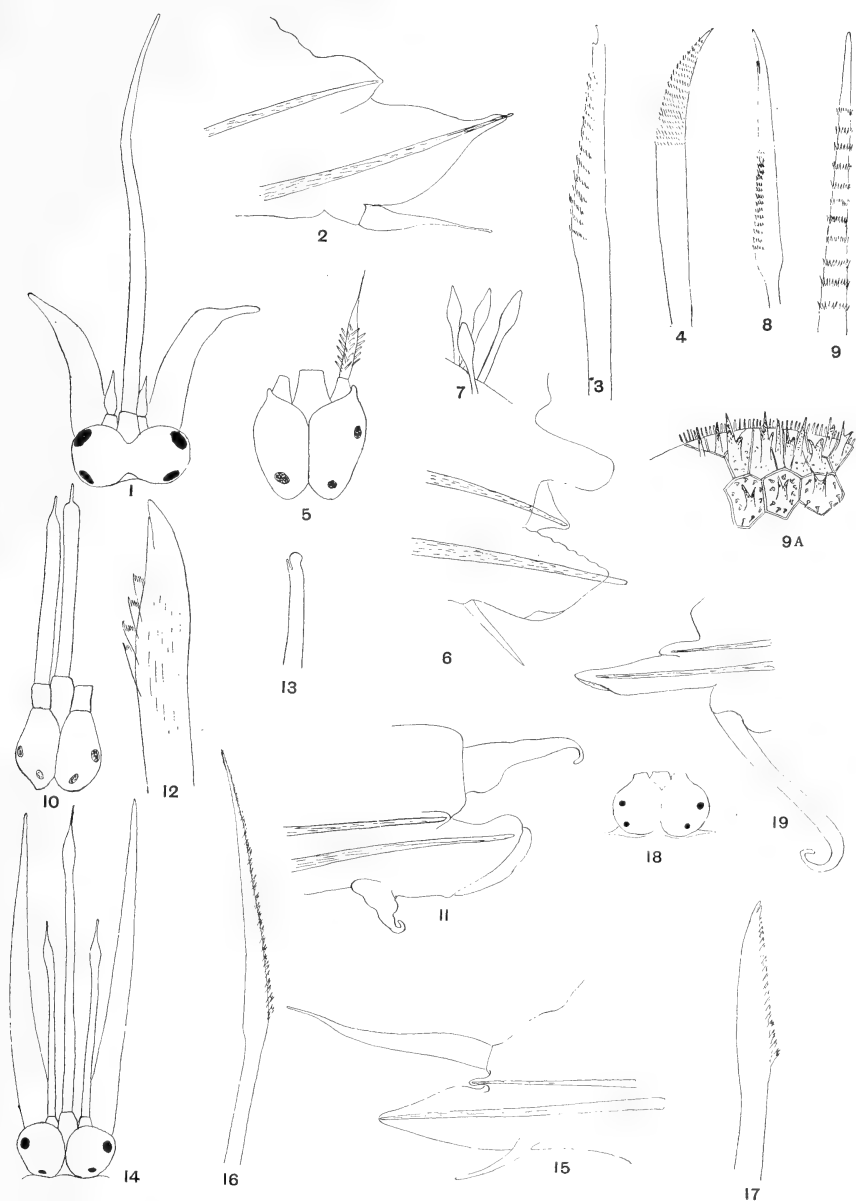


FIG. 177. 1, *Harmothoe sylliformia*, anterior end  $\times 25.5$ ; 2, parapodium  $\times 45$ ; 3, neuropodial seta  $\times 185$ ; 4, notopodial seta  $\times 215$ ; 5, *Harmothoe lanceolata*, anterior end  $\times 30$ ; 6, parapodium  $\times 85$ ; 7, detail of cilia on cirrus  $\times 85$ ; 8, neuropodial seta  $\times 250$ ; 9, notopodial seta  $\times 250$ ; 9a, detail of elytron  $\times 27.5$ ; 10, *Lepidasthenia picta*, anterior end  $\times 10$ ; 11, posterior parapodium  $\times 15$ ; 12, seta  $\times 185$ ; 13, seta from first parapodium  $\times 250$ ; 14, *Lepidasthenia rufa*, anterior end  $\times 25$ ; 15, parapodium  $\times 45$ ; 16, dorsal seta of neuropodium  $\times 250$ ; 17, ventral seta of neuropodium  $\times 250$ ; 18, *Lepidasthenia variegata*, anterior end  $\times 12.5$ ; 19, first parapodium  $\times 27.5$ .

One specimen very poorly preserved agreeing with McIntosh's description except that the simple setae are smoother than he figured. I was also unable to find the bifid setae which he said sometimes occur. The hooks on the neuropodia are invaginated leaving small pits. Augener (Zool. Anzeiger Bd. 36, p. 247, 1910) showed that the "parasites" recorded by earlier writers on the ventral surface of this species are really the young. Augener also questions the accuracy of the belief that this species normally lives in the valves of the barnacle. Collected at 2589.

#### Family APHRODITIDAE.

##### *Pontogenia* Claperede.

##### *Pontogenia sericoma* Ehlers.

*Pontogenia sericoma* Ehlers, 1887, p. 46, pl. 7, figs. 1 to 5.

Collected at 17° 39' N., 63° 17' W., in 100 meters on Saba Bank, one specimen. Pedunculate eyes are commonly given as a character of this genus but Ehlers (loc. cit. p. 46), states that the eyes are sometimes on "Polstern" as in the species here described. The single specimen in this collection has lost its median tentacle and its anal cirri.

#### Family POLYNOIDAE.

##### *Laetmonice* Kinberg.

##### *Laetmonice kinbergii* Baird.

*Laetmonice kinbergii* Baird, 1865, p. 180.

Collected at 30° 0' N., 74° 02' W., one specimen; 4° 50' N., 87° 0' W., one specimen.

##### *Hermenia* Grube.

##### *Hermenia verruculosa* Grube.

*Hermenia verruculosa* Grube, 1856, pp. 44, 45.

Treadwell, 1911, pp. 9 to 11, figs. 23 to 26.

Collected at 17° 39' N., 63° 17' W., in 100 metres.

##### *Harmothoe* Kinberg.

##### *Harmothoe sylliformia*, sp. nov.

(Fig 177: figs. 1 to 4.)

Large specimens are 9 mm. long and 1.25 mm. wide. In size and general appearance they resemble short, thick bodied syllids, this resemblance being heightened by the dark red color of the pharynx visible to the naked eye; this being a common occurrence among the syllids. While I am unable to fit them into any established genus I am listing them as *Harmothoe* in the belief that they are immature individuals. They have large anterior eyes and thirteen instead of fifteen pairs of elytra in both of which characters they differ from the diagnosis of *Harmothoe*. Also, the elytra have only traces of roughnesses on their surfaces.

The prostomium (figure 1) is 0.75 mm. broad and about half of that in length, and is covered by the first pair of elytra. It is transversely oval in

outline, and is divided dorsally by a median longitudinal division into two lobes, the lateral margin of each lobe being, except for a small anterior portion, nearly semicircular in outline. Both pairs of eyes are large and supplied with lenses. The anterior pair face antero-laterally and are a trifle larger than the posterior pair which face latero-posteriorly. The cirrophore of the median tentacle occupies the middle of the anterior margin. It is relatively rather heavy and its style is very long, as much as seven times the length of the prostomium. The preservation of these cirri was not very good, but it apparently terminates in a blunt point. With high magnification it is possible to see on its surface a few sparsely distributed club-shaped cilia. The paired tentacles lie latero-ventrally to the median on short cirrophores. The styles are elongated flask-shaped, the whole cirrus being hardly longer than the prostomium. A few cilia may be seen on the surface. The dorsal tentacular cirrus is about the size of the median tentacle, the ventral one about one half as long as this. The palps are about four times as long as the prostomium, taper from the base but at about the beginning of the terminal fourth enlarge slightly and terminate in an acute tip. There is a trace of pigment at the enlarged region. The dorsal cirri of anterior somites are shorter than the median tentacle but resemble it in form. They are similar in form throughout the body but become slightly shorter posteriorly. I was unable to find any anal cirri.

The first somite has no neuropodium, its notopodium being represented by a pair of stout brown setae. The second somite has a complete parapodium, the notopodial setae being about 25 in number, arranged in a dorso-laterally directed whorl. The neuropodial setae are more slender than the notopodial but are longer than they and make up a tuft extending fully twice the length of the parapodium beyond its apex. The parapodium (figure 2) has conical neuropodial and notopodial lobes the latter much the smaller of the two, and without the slender terminal lobe found in the former. Each has one acicula and in each the setal gland is conspicuous.

The neuropodial setae (figure 3) have long shafts followed by a broader portion carrying transverse rows of teeth. This portion narrows and ends in a terminal tooth, with a much smaller subterminal tooth lying just proximal to this. The notopodial setae are much shorter and thicker than the neuropodial. They curve very slightly to the pointed apex and carry numerous transverse rows of toothed plates (figure 4). The cirrophore of the ventral cirrus is carried well toward the apex of the parapodium. Its style is shaped like that of the paired tentacle and extends beyond the end of the parapodium.

The elytra are very thin and transparent so that under a lens it is sometimes difficult to see if they are present. Beyond the statement that they have smooth margins and are approximately circular in outline not much of importance can be said about them.

The protruded pharynx is, because of its pigmentation, in marked contrast to the remainder of the body. It is a club shaped mass on which I could find no trace of terminal papillae or teeth.

The type was collected at  $0^{\circ} 17' \text{ S.}, 91^{\circ} 34' \text{ W.}$ , in 300 to 500 fathoms and is in the collections of the New York Zoological Society. Others were collected at the following localities;  $2^{\circ} 0' \text{ S.}, 89^{\circ} 30' \text{ W.}$ , in 700 fathoms; 11 specimens



and in 400 fathoms, one specimen; 0° 0' S., 91° 53' W.; 4° 50' N.; 87° W., in 500 fathoms; 0° 42' S., 91° 47' W., large number, no depth given; 0° 5' S., 91° 11' W., a few in 250 fathoms; 0° 17' S., 91° 34' W., large number, no depth given; 0° 20' N., 90° 10' W., two in 200 fathoms; 1° 51' S., 89° 50' W., in 1463 meters.

*Harmothoe lanceocirrata*, sp. nov.

(Fig. 177: *figs. 5 to 9A.*)

The type specimen contains 25 somites but is incomplete posteriorly so that the anal cirri are lacking. Whether any posterior somites are also lacking is difficult to determine but from the way the body narrows in this region it seems probable that they are not. Twelve pairs of elytra completely cover the whole body. At its widest point, not counting the parapodia, the body is a trifle over 2 mm. in diameter and is 15 mm. long. The prostomial width is about 0.5 mm.

The prostomium (figure 5) is a little narrower posteriorly than anteriorly; the posterior angles are rounded and there is a slight lateral bulge. The anterior margins are formed by the acute peaks. The posterior eyes lie near the posterior margin of the prostomium, near the outer angle but on the dorsal surface. In the type the left posterior eye appears double and there is no left anterior one. This is obviously an abnormality. The right anterior eye is on the margin at the point of greatest prostomial width. The median tentacle is lost, but its cirrophore occupies rather more than one third the anterior margin of the prostomium and is nearly one third as long as the prostomium. Its proximal two thirds is faintly marked with brown. The cirrophore of the paired tentacle is about one half as long and wide as that of the median one and is situated below and a little to the median line of the nipple-shaped peak. Its basal half is reddish brown in color. Only the right paired tentacle is present. This is about three times as long as the cirrophore, is faintly tinted with brown and except at the end, is densely "ciliated." It terminates in a delicate colorless process. All tentacular cirri had been lost in the type.

The left palp at its base, is somewhat thicker than the cirrophore of the median tentacle and it is about six times as long as the prostomium, tapering gradually to a very acute apex. The surface is thickly covered with minute cilia, much shorter than the ones on the lateral tentacle. The right palp is much shorter and lighter colored than the left and is evidently regenerating. The cirrophores of the tentacular cirri are more slender than that of the median tentacle and are about as long as it.

The parapodia have a long neuropodium, (figure 6) obliquely truncated at the apex. Its dorsal margin slopes inward and dorsally in the fashion characteristic of this family, to the notopodium. Each parapodial lobe has a single acicula. Setae arise toward the anterior faces of the lobes and the dorsal cirrus is carried on a heavy cirrophore near the top of the posterior surface of the notopodium. The dorsal cirrus has a stout main axis, is longer than the parapodium and tapers gradually to near the end where it narrows very decidedly to a slender portion which is of uniform width until at the apex where there is a small knob. At the base the cirrus is smooth but cilia appear distally; at first

few in number but farther out they increase in number and size until at rather less than half the length of the cirrus they equal in length the transverse diameter of the cirrus. They are, throughout the greater part of the cirrus, very closely crowded together so that accurate drawings are impossible. A detail is shown in figure 7. The figure shows the structure of the cilia taken from beyond the middle of the cirrus. Proximally they are more typically cylindrical in form and this form returns at the apex but through the middle region the long lanceolate form is very prominent. Under a hand lens the cirrus because of these cilia, has a feathery appearance. The ventral cirrus is slender and tapering, ending in a rounded tip just beyond the apex of the neuropodium.

The neuropodial setae are longer than the notopodial but more slender. They vary somewhat in length but the longest extend from the body to a distance as great as the length of the notopodial lobe. The basal portion is smooth. Toward the apex each widens into an unsymmetrical lanceolate form and this region from its base to a little beyond its middle, carries transverse rows of toothed plates. The end is smooth, with a terminal and a subterminal tooth. The latter is much the smaller of the two (figure 8). The notopodial setae vary greatly in length, some being nearly as long as the neuropodial. The longest are at the ventral end of the tuft and dorsally they decrease in length, those at the dorsal margin being free for less than half their length. They all have stout central axes, carrying transversely arranged toothed plates for the greater part of their free portions (figure 9).

The elytra overlap in the mid-dorsal line, completely covering the dorsal surface and the head. The most anterior ones are kidney shaped, later ones through the filling up of the "hilus" in the kidney, becoming more nearly oval in outline. This filling material is in contrast with the remainder of the elytron in that it is smooth and delicate, the remainder of the elytron surface being studded with sharp spines. Figure 9A gives a detail of this surface from an elytron near the middle of the body. The portion of each elytron overlapped by the preceding one is smooth. Passing from this toward the exposed surface there first appear minute polygonal areas each bearing in its centre a short stout spine. Passing posteriorly over the free surface these areas become larger, are four or five sided, with heavy boundary lines and the spines become very prominent. The largest spines lie near the posterior margin of the elytron each occupying the centre of a polygonal area while smaller spines lie in a single row around it. The number of these smaller spines varies with the size of the area, twelve being the largest number that I saw. The free margin of the elytron carries a row of "cilia" those on the lateral margin being the largest and most densely clustered. In this preserved specimen the body is flesh-colored, the dense portions of the elytra being of a slightly deeper tint.

The type was collected at 17° 39' N., 63° 17' W., and is in the collections of the New York Zoological Society. A second specimen from the same locality has lost all elytra and all but one dorsal cirrus and is incomplete posteriorly. The median tentacle is also lost. The tentacular cirri are unequal in size, the dorsal one being rather more than half as long as the palp. Both cirri have prominent cilia like those found on the tentacles. They do not have the lanceolate cilia found in the dorsal cirri. Both anterior eyes are present.

*Lepidasthenia* Malmgren.*Lepidasthenia picta*, sp. nov.

(Fig. 177: figs. 10 to 13.)

The type and one much smaller specimen from which all elytra had been lost. The body of the type is 55 mm. long and 4 mm. wide at the eighth somite. From this point it tapers to an anal width of 0.5 mm. and a prostomial width of 1 mm. The most noticeable feature of the animal is the body-color. The prostomium is colorless except for the eyes and a faint dusting of pigment on the ceratophores of the tentacles. Somite 1 has (in preserved material), a brownish patch on the dorso-median line and one on either postero-lateral margin extending slightly on to the bases of the tentacular cirri. Somites 2 and 3 have each a dorsal median patch with more or less pigment laterally and on the parapodial bases. In somites 4 and 5 the dorsal median area is uncolored and there is a dense mass of pigment on either side of this. The lateral region is not pigmented but the bases of the cirrophores are. Somites 6 and 8 are mostly not colored while 7 has its dorsal surface completely pigmented, with some of this pigment extending slightly over 6 and 8. The lateral region of 7 is not colored but there are traces of pigment on the bases of the parapodia. Behind somite 8 the dorsal coloration is not entirely uniform but in general it has the form of a median band extending laterally as far as the parapodial bases interrupted by occasional colorless patches. The most uniform of these patches are rectangular occurring every 3 or 4 somites. This coloration is continued to the extreme posterior end, being lighter posteriorly. Anteriorly the ventral surface is unpigmented except for a very little around the mouth. At about somite 24 pigment appears. This intensifies farther back so that the latter half of the body is densely pigmented on either side extending on to the ventral cirri, while the mid-ventral region is uncolored.

The prostomium (figure 10) is rather narrower at the posterior than at the anterior border, each of its halves being rather longer than wide. The posterior eyes are on the dorsal surface at some distance from the margin while the anterior ones are lateral in position. The eyes are all of about the same size. The ceratophores of the lateral tentacles are relatively rather heavy, nearly as large as the median, which is partly covered laterally by their margins. The median extends a trifle beyond the lateral ones. The median tentacle is about four times as long as the prostomium and is nearly uniform in width to near the apex when it narrows abruptly into a filiform tip. The lateral tentacles are similar to the median in form but are a very little more slender and not quite so long. The palps have heavy bases but are broken in the specimen, only a portion less than half as long as the tentacle remaining. The dorsal cirri have been lost from most of the anterior somites. The posterior ones (figure 11) are about as long as the setal lobe, and have swollen bases and acute ends. A finger shaped cirrus at the posterior end is apparently one anal cirrus but this end is not well preserved and it may be a distorted dorsal cirrus bent backward as a result of injury. There originally were more than 30 pairs of elytra, but they are all lost in the specimen.

The parapodia (figure 11 from posterior part of body), have post- and presetal lobes of which the former is a trifle the longer and a single row of setae between them. The notopodium is rudimentary and has no setae but contains a single acicula. A single larger acicula lies in the neuropodium. The dorsal cirrus has a swollen base and its acute apex extends beyond the setal lobe. The ventral cirrus is rather stout, lies well out on the parapodium and its apex does not reach the end of the setal lobe. The posterior parapodia are longer with reference to the general body width than are the anterior ones, but in other respects they do not differ.

Most setae have rather heavy shafts which widen slightly toward the ends and carry apical and subapical teeth the former much the larger (figure 12). This terminal wider portion is longer in anterior than in posterior somites and carries a few rows of toothed plates. Most of the anterior setae are broken, but they evidently in life protruded from the body wall much less than did the posterior ones. In the first parapodium are no toothed setae but only a few simpler ones (figure 13), having the apex rounded beyond a slight constriction and carrying a subapical tooth. Owing to lack of material I did not attempt to determine the distribution of these setae. The type is in the collection of the New York Zoological Society. Both specimens were collected at 1° 22' S., 89° 39' W., in 15 feet.

*Lepidasthenia rufa*, sp. nov.

(Fig. 177: *figs.* 14 to 17.)

One specimen approximately 25 mm. long and 1.5 mm. wide.

In the preserved material a noticeable feature is the series of rusty brown blotches covering anteriorly nearly the whole dorsal surface but posteriorly leaving considerable areas uncolored especially along the mid-dorsal line. This effect is produced by the coloration of the elytra which are primarily thin and transparent so that the body wall shows through them. In the middle of the body each elytron has a rusty-brown patch covering its anterior third, with a continuation of this color in a band extending posteriorly through the centre of the elytron, leaving the inner and outer portions uncolored. Since the body wall is visible through the uncolored part of the elytron the effect is that of a colorless body with a series of rusty brown spots on either side. Anteriorly these blotches cover more of the surface except for the first pair of elytra which are transparent and extend beyond the prostomium to a distance equal to one third the length of the palps. Figure 14 of the head region was drawn without removing the first elytron. The elytra are more or less curled in the preserved material but apparently originally covered the entire dorsal surface. There are approximately sixty somites and twenty two pairs of elytra of which the first extend beyond the head as already stated and the last completely cover the anal cirri. On the dorsal surface are two small pigment patches, one at the base of each parapodium and one on the cirrophore of the dorsal cirrus. On the ventral surface is a patch on the base of each parapodium.

The prostomium is approximately 0.5 mm. in width and 0.25 mm. long, in outline a nearly symmetrical oval (figure 14). There are two pairs of eyes, one, the larger pair, near the widest part of the prostomium, the other near its

posterior border. There is a wide but rather shallow depression on the posterior margin and a narrow median groove extends forward from this to the base of the median cirrophore. The latter is inserted in a shallow depression at the anterior margin of the prostomium and is not more than one fourth as long as the prostomium. The style of the median tentacle is eight times as long as the prostomium. It tapers very slightly from its base to near the end where there is a subterminal swelling and final filamentous tip. The lateral tentacles resemble the median in form but in length and breadth are about two thirds as large. At their bases the palps are fully one half as wide as the prostomium and taper gradually to the apices which are at about the level of the end of the median tentacle. The surface of the palps is perfectly smooth.

The tentacular cirri are shaped like the tentacles, the dorsal ones about equal in size to the median; the ventral ones to the lateral tentacle. The first three dorsal cirri are prominent, resembling the tentacular cirri in form, but are broader basally and the terminal enlargement is smaller. Behind the fourth one they are smaller and in the middle of the body lack the terminal enlargement. The ventral cirri are throughout small and inconspicuous. The anal cirri resemble the posterior dorsal ones in form.

The parapodia (figure 15) are essentially similar in form throughout the body, the first few being smaller than the others. The neuropodium has conical post- and presetal lobes, the latter being the longer. The notopodium is rudimentary and carries no setae. A single acicula extends into it.

There are two kinds of neuropodial setae (figures 16, 17). Both have long shafts smooth nearly to the ends. Near the ends they enlarge and this enlarged portion carries rows of toothed plates along its convex surface. The dorsalmost of the setae are the more slender and the terminal portion longer than in the ventral ones. In both kinds the apices are bifid.

The protruded pharynx is in length about equal to the first ten somites. Its surface is smooth. Dorsal and ventral conical papillae occur on the margin of its aperture which carries also two teeth above and below.

The elytra are irregularly oval in outline throughout and their unpigmented portions are very transparent. The pigment occurs in distinct angular masses closely packed together, its distribution over the surface being as above indicated. There is no trace of either marginal cilia or of spines.

The type and only specimen was collected at 17° 39' N., 63° 17' W., and is in the collections of the New York Zoological Society.

*Lepidasthenia variegata*, sp. nov.

(Fig. 177: *figs.* 18, 19; Fig. 178: *figs.* 20, 21.)

A single incomplete individual which is so unlike any description I can find for species of this genus that it seems best to record it even though a study of better material may make a renewed description necessary. The fragment is approximately 12 mm. long and has a body width of 1.5 mm. in the widest portion at about the eighth somite. 35 somites are represented. The prostomium and the median dorsal region of the body are uncolored. On either side of the body is a dorso-lateral pigmented region, composed in each somite

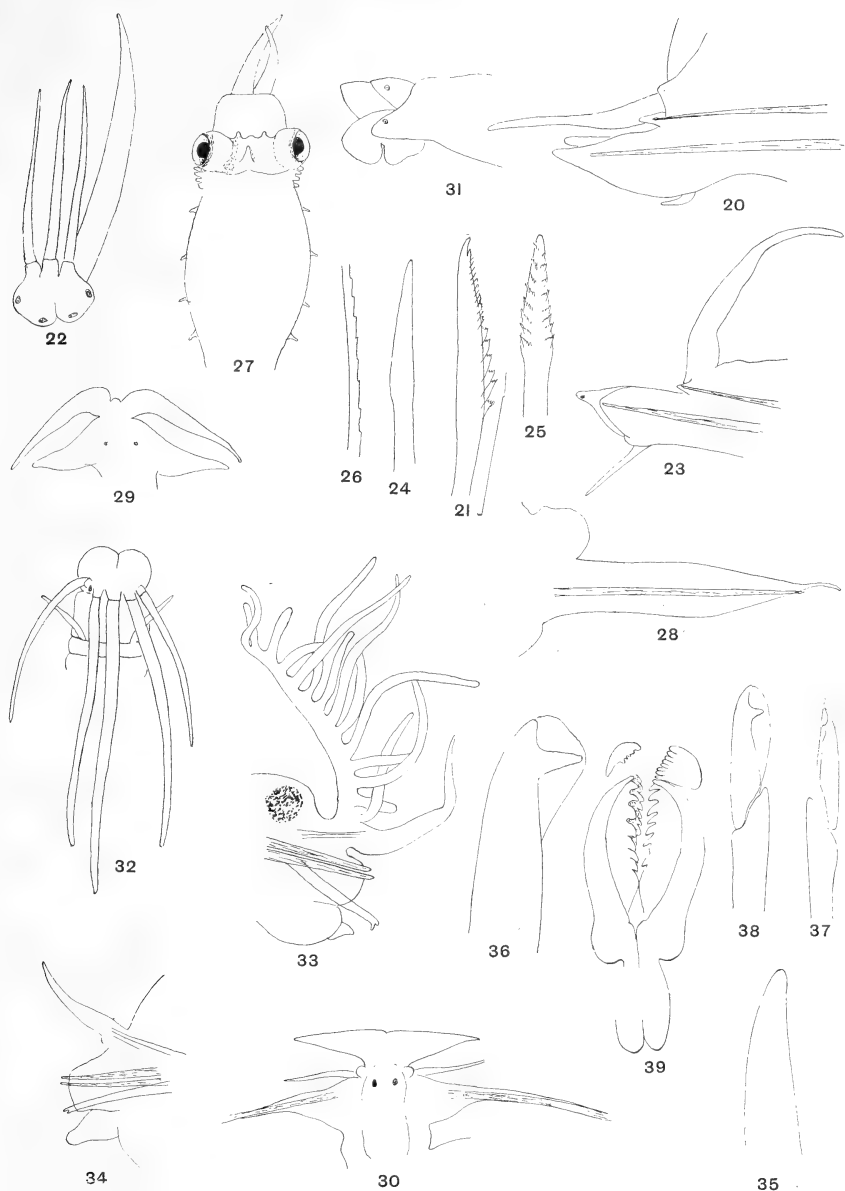


Fig. 178. 20, *Lepidasthenia variegata*, 18th parapodium  $\times 27.5$ ; 21, seta of 18th parapodium  $\times 185$ ; 22, *Lepidasthenia longicirrata*, anterior end  $\times 10$ ; 23, parapodium  $\times 20$ ; 24, notopodial seta  $\times 250$ ; 25, 2nd form of notopodial seta  $\times 250$ ; 26, detail of dorsalmost notopodial seta  $\times 250$ ; 27, *Vanadis collata*, anterior end  $\times 5$ ; 28, 49th parapodium  $\times 18$ ; 29, *Tomopteris opaca*, anterior end  $\times 5$ ; 30, *Tomopteris tentaculata*, anterior end  $\times 27.5$ ; 31, parapodium  $\times 27.5$ ; 32, *Leodice arcturi*, anterior end  $\times 5$ ; 33, 25th parapodium  $\times 27.5$ ; 34, posterior parapodium  $\times 27.5$ ; 35, dorsal acicula from posterior parapodium  $\times 250$ ; 36, ventral acicula from posterior parapodium  $\times 250$ ; 37, seta from 25th parapodium  $\times 250$ ; 38, seta from posterior parapodium  $\times 250$ ; 39, mandible  $\times 30$ .

of three bands running transversely and close together to the base of the parapodium. In elytron-bearing somites these bands extend on to the elytophore but in the others they stop at the parapodial base. The remainder of the parapodial surfaces are without pigment. On the ventral surface there is a similarly colored pigment spot at the base of each parapodium.

Only two elytra remain and these are the last two on the left side. They overlap one another and extend beyond the median line dorsally. In life the dorsal surface of the body must have been entirely covered by the elytra. Each elytron has a smooth margin and the two that remain are nearly circular in outline. A pigment patch occupies the dorso-median portion of the elytron, covering about one third of its area and from this a narrow band of pigment extends posteriorly in the direction of the elytophore of the next elytron. This pigment is similar in color to that on the body wall. The remainder of the elytron is translucent-white and smooth.

The prostomium (fig. 18) is rather less than 1 mm. wide and 0.5 mm. long. The eyes are equal in size and prominent. All tentacles, cirri and palps are lost. The protruded pharynx extends 4 mm. in front of the prostomium. On each of its dorsal and ventral margin is a row of nine papillae, each papilla having a prominent pigment spot at about its middle. There are two pairs of teeth.

The first parapodium (fig. 19) has a slender neuropodial lobe, obliquely truncated at the apex, which carries pre- and post-setal lips. The notopodial lobe is vestigial and carries an acicula but no setae. The ventral cirrus is longer than the neuropodial lobe, and its cirrophore is colored brown. Dorsally this parapodium carries an elytophore. The eighteenth parapodium (fig. 20) has a thick conical neuropodial lobe bifid at the end and a vestigial notopodium, each lobe as before containing an acicula. The dorsal cirrus is slender and a little longer than the neuropodium while the ventral one is very small and situated near the parapodial base.

The setae of the eighteenth parapodia are all alike, expanding toward the ends and terminating in a larger apical and much smaller subapical tooth (figure 21). There are numerous rows of toothed plates proximal to these. These rows of plates are much more numerous than they are in *L. picta* (see figure 12, plate 1) and the plates are smaller. The setae of the first somite terminate in the rounded ending figured for *L. picta* (see fig. 13, plate 1) but have numerous rows of toothed plates proximal to this. It seems probable that fig. 13 is of an immature seta and that if fully developed it also would show these plates. This, however, was not apparent in the single specimen at my disposal.

Collected at 17° 39' N., 63° 17' W., in 125 fathoms.

The type is in the collections of the New York Zoological Society.

*Lepidasthenia longicirrata*, sp. nov.

(Fig. 178: figs. 22 to 26.)

A single specimen. All body somites are present but the only elytron represented is one of the last pair. There originally were eighteen elytra on either side. The body is 13 mm. long and 1.5 mm. wide. A noticeable feature

is the great length of the parapodial cirri, the dorsal one extending beyond the setae while the ventral one is longer than the setal lobe.

The prostomium (figure 22) is transversely oval in outline, widest at the level of the anterior pair of eyes. The prostomial width is 0.5 mm. On its anterior margin is a broad shallow incision filled by the cirrophore of the median tentacle. On the posterior border is a deeper but narrower incision. The median tentacle is broken at the end but apparently was four to five times as long as the prostomium, slender and gently tapered. Its cirrophore fills the marginal incision and overlaps on either side, partly covering the cirrophores of the lateral tentacles. The styles of the lateral tentacles are similar in form to the median but are more slender. The tentacular cirri are similar in form and size to the tentacles and to the dorsal cirri. The palp at its base is broader than half of the prostomial width, at first tapers gradually, later more abruptly, to end in an acute tip. The dorsal cirri throughout are like the one shown in figure 23 but become shorter posteriorly. There is one pair of slender anal cirri. The palps appear smooth but under a magnification of about 100 diameters they show numerous transverse rings and very small cilia. The protruded pharynx is about ten times as long as the prostomium and has the usual arrangement of terminal papillae and teeth. The teeth are light brown in color each with a darker brown axial pigment line.

The elytra which remain are nearly circular in outline and transparent, and completely cover the last three body somites.

The parapodia are essentially similar throughout the body, figure 23 being of the eighth. The neuropodium has parallel dorsal and ventral margins, but is beveled at the end. The notopodium is represented only by a minute lobe into which the acicula extends. A very few simple setae occur in the notopodium (figure 24). The neuropodial setae are of two kinds. The dorsal ones in each tuft are very slender and sharp pointed and extend beyond the parapodium to a distance equal to the parapodial length. In the parapodium figured there were ten of these. Each has a row of minute teeth along one side. A detail of this is shown in figure 26. On the ventral end of the seta tuft the setae have stouter shafts than the above variety, and a lanceolate terminal portion carrying two rows of toothed plates which in profile may look like one (figure 25). In progression dorsally from these the setae become more slender and the lanceolate portion longer until at the top they are hardly larger than those of the dorsalmost tuft. The toothed plates are always restricted to the lanceolate ends.

The type was collected at 4° 50' N., 87° W., and is in the collections of the New York Zoological Society.

From this same locality was taken three small and one larger specimens which may belong to this species. The lateral prostomial borders are more rounded than in the type and the eyes more prominent. In each half of the prostomium of the larger specimen is a dark gray patch occupying nearly one half its surface and covering its anterior eye. Another very small specimen similar to these last was collected at 2° S., 89° 30' W., in 700 fathoms. No elytra are present in any of these. A constant feature is a brown pigmentation on each elyrophore.



## Family ALCIOPIDAE.

*Rhynchonerella* Costa.*Rhynchonerella pycnocera* Chamberlin.

*Rhynchonerella pycnocera* Chamberlin, 1919, pp. 147 to 150, pl. 25, figs. 7, 8; pl. 26, figs. 1 to 6.

One specimen collected at 1° 20' S., 89° 33' W., in 50 fathoms. I was unable to find the stouter setae with very delicate terminal joints figured in Chamberlin's pl. 26, fig. 6, but in other respects this agrees with his description. Fragments belonging to this species were also taken at 1° 32' S., 89° 30' W., and at 0° 17' S., 91° 34' W.

*Vanadis* Claperede.*Vanadis fusca-punctata* Treadwell.

*Vanadis fusca-punctata* Treadwell, 1906, pp. 1159, 1160, figs. 29, 30, 31.

The only differences I could find between these and the original description of this species are that the tentacles are stouter and the whole prostomium has a more swollen appearance in the *Arcturus* material. Two specimens collected at 3° 52' N., 86° 43' W., in 600 fathoms; one at 0° 0', 91° 53' W.; one at 5° 03' N., 81° 98' W., in 250 metres; one at 5° 28' N., 86° 54' W., on the surface.

*Vanadis collata*, sp. nov.

(Fig. 178: figs. 27, 28.)

An incomplete specimen, retaining the anterior end. This fragment is 85 mm. long and has a body width of 2.5 mm. in the region of the twenty-fifth setigerous somite. Between the first and the fifth somite is a pronounced bulging of the body both dorso-ventrally and laterally the latter much the more pronounced. I am uncertain if this is natural or if it may be due to the action of preserving fluids. The specific name has reference to the feeble development of the first ten pairs of parapodia, giving the animal the appearance of having a definite neck.

The prostomial diameter at the eyes is 2.75 mm., its length 1 mm. The anterior margin is obscured by the partly protruded pharynx and the whole head region is apparently not well preserved. Of the characteristic head appendages I was able to see only two minute elevations on the margin corresponding to the dorsal marginal tentacles and a dorsal median one lying between the eyes. Tentacular cirri are represented only by four stout protrusions on either side (figure 27).

The eyes are very large and the lenses point dorso-laterally. The cup of the eye is chestnut brown, the lens a dark reddish brown. The pharynx is partly protruded, its bifid end visible.

Aside from the eyes the only pigmentation on the specimen appears in the series of segmental glands which are present as prominent brown patches postero-dorsally to each parapodium in nearly all somites posterior to the twenty-fifth.

Apparently the anterior parapodia are badly preserved and not much can

be said about them except that they are very small. The seventh, eighth and ninth are progressively somewhat larger but the tenth is the first to assume the characteristic form. There are sixty-two setigerous somites in the body and the parapodia reach full size in the region of the thirtieth. The parapodium (figure 28 of the 49th), is uniramous, of nearly uniform diameter until near the end, when it widens and then narrows to a very acute tip, bearing a single slender cirrus at the end. The single large acicula comes to the surface just posterior to this. There is a dense tuft of slender colorless setae but I was unable to find any that are entire. Dorsal to the base of the parapodium is a rounded lobe looking like a feebly developed cirrophore, and just behind this the pigment marking the position of the glands.

One specimen, collected at 2° 0' S., 89° 30' W., in 400 fathoms. The type is in the collections of the New York Zoological Society.

*Greefia* McIntosh.

*Greefia oahuensis* McIntosh.

*Greefia oahuensis* McIntosh, 1885, pp. 182, 183; pl. 28, figs. 5, 6; pl. 32, fig. 11, pl. 15A, fig. 4.

The largest specimen is a mature female retaining only the first fifty somites. These measure 45 mm. in length. Collected at 2° 0' S., 89° 30' W., in 1200 fathoms. One smaller one was taken at 2° 33' S., 89° 44' W., in 300 meters; one, probably immature, at 4° 50' N., 87° W., in 300 fathoms and one fragment at 6° 10' N., 8° 11' W., on the surface.

Family TOMOPTERIDAE.

*Tomopteris* Eschscholtz.

An aberrant genus of annelids, generally having a transparent body (see, however, *T. opaca* below), and apparently showing a considerable degree of individual variability. The peculiar form of the prostomium with its unusually heavy tentacles, the lack of setae except in the two cirri, and the exaggerated development of the second cirrus, are distinguishing features of the genus. Two characters often relied on for species determination viz. the presence or absence of the second cirrus, and the "tail," carrying feebly developed parapodia seems, however, to be largely subject to individual variation. Apstein (1900, pp. 34, 35) states that the first cirrus is so well protected by its position that it seems unlikely that its occasional absence is due to injury, and it seems probable that the presence or absence of the tail is a matter depending on the maturity of the individual.

*Tomopteris opaca*, sp. nov.

(Fig. 178: fig. 29.)

While the members of this genus are characteristically transparent, this species has a heavy, opaque body, the opacity resulting from the structure of the body wall. The largest individual is 4 mm. wide and 27 mm. long. The type is 3 mm. wide and 13 mm. long.

In the largest specimen the body in both dorsal and ventral median lines

is black. Lateral to this on either side the color is as if this black tint extends to the body margin but is overlaid by a translucent yellowish material of the same color as the parapodium. In this preserved material this layer shows constrictions at the intersegmental grooves but is swollen between them, appearing almost like a series of elytra. The parapodia are colored a dense opaque yellowish white. Smaller specimens do not show the black coloration but in other respects are like the above description.

In the type the body is widest at about its median point. This is partly due to a greater width of the body proper, and partly to a greater length of the parapodia in this region. From here it tapers in either direction, the tapering being rather slight anteriorly and much greater posteriorly where it narrows to about 0.5 mm. diameter. There are twenty pairs of parapodia the posterior ones very short. There is a smooth caudal process about 1 mm. long, which appears to be entire but of this I could not be certain. A similar process is present in one other specimen but is badly macerated in the others.

The tentacles (figure 29) are stout and extend beyond the apices of the second tentacular cirrus lobes. There are no first tentacular cirri. The second tentacular cirri have stout conical basal portions, and slender terminal portions considerably longer than the body. This is not well enough preserved in any of this material to allow of accurate measurements. The parapodia are heavy, bifid at the ends and have more or less fluted terminal expansions on both branches. Owing to imperfect preservation I cannot give any further details.

The type and paratype were collected with two others at 4° 50' N., 87° W., in 550 and 700 fathoms. The type is in the collection of the New York Zoological Society, the paratype in the American Museum of Natural History.

One other species of *Tomopteris* has been described as opaque. Quatrefages 1865, pp. 227 to 229, pl. 20, figs. 1 and 2, states that *T. carpenteri* is maroon colored. Benham 1921, pp. 61 to 64, identified as *T. carpenteri* a species collected at Commonwealth Bay and gave a more complete description. This had the opaque body and dark dorsal and ventral areas I have described in *T. opaca*. The latter species differs from *carpenteri* in details of head structure.

*Tomopteris tentaculata*, sp. nov.

(Fig. 178: figs. 30, 31.)

The transparent body of the type is 6 mm. long and about 0.75 mm. wide, the total width, counting the parapodia, being 1.5 mm. The alimentary canal has relatively heavy walls and is about 0.5 mm. wide thus occupying nearly the whole body width. The tentacles are triangular in form with sharp apices, hardly extending beyond the bases of the second cirri (figure 30). The first cirri are slender, gently curved and shorter than the tentacles. The second cirri have heavy triangular bases and are about long enough to touch the fourth parapodia. The free portion of the seta is shorter than the body. There are twelve pairs of parapodia with, on the lateral body line, very slight intervals between them. The parapodium has a thick body, bifurcated at the end (figure 31) each terminal branch having the characteristic fin shaped processes. These are more or less macerated and the figure is the best drawing I could get.

The specimen was mounted in glycerine and was slightly crushed by the weight of the cover glass which somewhat modified its form. In the type, red-brown rosette organs are in the body of each first and second parapodium, and one in each apical branch of subsequent parapodia, situated near the base of the fin. The eyes are oval, red-brown in color. The brain is transverse oval with the anterior margin straight. There is no trace of a tail in either specimen. A second specimen, approximately equal in size to the type, has on the right side the same arrangement of rosette organs as the type but on the left side these do not appear in the first two parapodia and there is only one, in the body of the third parapodium. This latter specimen contained numerous eggs in cleavage stages, in its body cavity. Evidently fertilisation is internal. The type was collected at 4° 50' N., 87° W., at the surface, and is in the collections of the New York Zoological Society.

Other fragments of *Tomopteris* sp. were taken at the surface at 1° 32' S., 89° 30' W., and one at 2° S., 89° 30' W., at 1100 fathoms.

#### Family SYLLIDAE.

##### *Syllis* Savigny.

##### *Syllis palifica* Ehlers.

*Syllis palifica* Ehlers, 1901, pp. 88 to 92, pl. 10, figs. 8 to 16.

A single specimen, poorly preserved. Only one cirrus is retained and that agrees with Ehlers' description. Only the thick setae with bifid ends remain. Ehlers records that the distribution of these and of the compound ones is variable, apparently dependent on conditions of sexual maturity. Collected at 1° 22' S., 89° 39' W.

##### *Trypanosyllis* Claperede.

##### *Trypanosyllis vittigera* Ehlers.

*Trypanosyllis vittigera* Ehlers, 1887, pp. 151 to 154, pl. 40, figs. 1 to 3.

I have identified these specimens as *T. vittigera* from Ehlers' description, although they do not agree with his figures. The two halves of the prostomium are much more definitely distinct from one another than is indicated in his figure 1, but in this respect it seems to me his figure does not agree with his description.

There are two kinds of setae. One has a long terminal joint as shown in Ehlers' figure 3, the other has a much shorter terminal joint. In a specimen from 100D1 which was much longer than the others the marginal "cilia" of the terminal joint do not appear. These may have simply been worn off as the edge is more or less roughened.

Ehlers describes the transverse pigment bands as confined to the anterior region. This is true in small specimens but in the largest they are continued to the extreme posterior end.

Collected at Station 83.1 and at 0° 16' S., 91° 23' W., six specimens.

##### *Trypanosyllis latifrons* Grube.

*Trypanosyllis* (*Syllis*) *latifrons* (Grube), 1878, pp. 178, 179.

I have identified this by the character of the dorsal pigmented bands on the somites, the broad short prostomium and the arrangement of the eyes.

Two specimens collected at 17° 39' N, 63° 17' W.

*Typosyllis* Langerhans.

*Typosyllis hyalina* Grube.

*Typosyllis hyalina* Grube, 1863, p. 45.

The only respect in which this differs from Grube's description is that the median antenna instead of being long and articulated is rather shorter than the palps and has only two segments. This seems to be a case of regeneration.

One specimen collected at 1° 22' S., 89° 38' W.

*Typosyllis corallicola* Verrill.

*Typosyllis corallicola* Verrill, 1900, p. 603.

In all respects except color these agree with Verrill's description, though none are as large as the maximum length he gives. Verrill describes the color (in formalin), as yellowish-white with pale-greenish pigment in the annuli of the cirri. Those of this collection have the body throughout a region roughly corresponding to the extent of the pharynx, covered with minute brown spots scattered over the surface.

Numerous, collected at 1° 22' S., 89° 39' W., Hood Id.

Family NEPHTHYDIDAE.

*Nephtys* Cuvier.

*Nephtys phyllocirra* Ehlers.

*Nephtys phyllocirra* Ehlers, 1887, pp. 131 to 134; pl. 38, figs. 7 to 11.

Ehlers described the neuropodium in this species as having a single lip. I find that in these specimens which correspond in other respects with his description, the neuropodium has anterior and posterior conical lips extending well beyond the bases of the setae. 3 specimens collected at 38° 0' N., 74° 02' W., 1 specimen collected at 39° 15' N., 72° 0' W., in 633 fathoms.

Family CHRYSOPETALIDAE.

*Chrysopetalum* Ehlers.

*Chrysopetalum riveti* Gravier.

*Chrysopetalum riveti* Gravier, 1908, pp. 108 to 110, pl. 7 figs. 31, 32; pl. 8, figs. 33, 34 (in reprint).

Gravier's specimen was 18 mm. long. This one is less than 9 mm. One specimen collected at 0° 16' S., 91° 23' W., Tago Cave Galapagos.

Family PHYLLODOCIDAE.

*Phyllodoce* Savigny.

*Phyllodoce oculata* Ehlers.

*Phyllodoce oculata* Ehlers, 1887, p. 135, pl. 40, figs. 4, 5, 6.

One specimen collected at 17° 39' N., 63° 17' W., in 100 meters. Another

specimen from this same station, labeled as taken at 125 fathoms is very much smaller and I have recorded it as a young of this species, basing the identification on the form of the head and protruded pharynx. The dorsal cirri are white as in Ehlers' description but they do not cover the dorsal surface.

*Phyllodoce varia*, sp. nov.

(Fig. 179: *figs.* 69 to 71.)

A single incomplete specimen retaining approximately 100 somites. The portion remaining is 17 mm. long and has a prostomial width of 0.5 mm. The anterior 50 somites are pale yellow in color while the remainder is colorless. In the colored region the dorsal surface is marked by fine dark pigment spots which are most noticeable in the median dorsal line but also occur on either side of this, extending nearly to the somite margin. This arrangement is most obvious in the anterior somites. Farther posteriorly the pigment is arranged in a band extending across the dorso-median line of the somite, and a small spot just posterior to this in the dorsal median line. The prostomium, all cirri, and parapodia are colorless.

The prostomium (figure 69) is cordate in outline, the eyes large and brown. The tentacular cirri are slender. The protruded proboscis is about as long as the first ten body somites and has on either side six rows of rounded papillae.

In the parapodium the setal lobe is notched at the apex and the acicula extends into this notch. The dorsal cirrus is lanceolate in outline and is not very broad. The ventral cirrus is relatively broader than the dorsal and is asymmetrically lanceolate in outline. The setae have the usual compound form with a relatively short terminal joint toothed on its concave margin (figure 70). The setae at the ventral end of the tuft are much more curved than are those at the upper margin.

The type was collected at 0° 22' S., 89° 29' W., and is in the collections of the New York Zoological Society.

*Phyllodoce tortugae* Treadwell.

*Phyllodoce tortugae* Treadwell, 1917, p. 262, *pl.* 2, *figs.* 4 to 6.

One specimen, collected at 17° 39' N., 63° 17' W., in 100 metres.

*Lopadorhynchus* Grube.

*Lopadorhynchus nans*, Chamberlin.

*Lopadorhynchus nans* Chamberlin, 1919, *pp.* 116 to 119, *pl.* 17, *figs.* 1 to 5.

One specimen, 14 mm. long collected at 1° 32' S., 89° 30' W. One specimen 16 mm. long, marked "♯79,68PT."

*Lopadorhynchus uncinatus* Fauvel.

*Lopadorhynchus uncinatus* Fauvel, 1916, *pp.* 57 to 61, *pl.* 1, *figs.* 2, 3; *pl.* 4, *figs.* 4 to 14.

Fauvel's specimens were collected in the region of the Azores and in the Mediterranean and differed from any previously described in the excessive development of the first two pairs of parapodia (as compared with succeeding

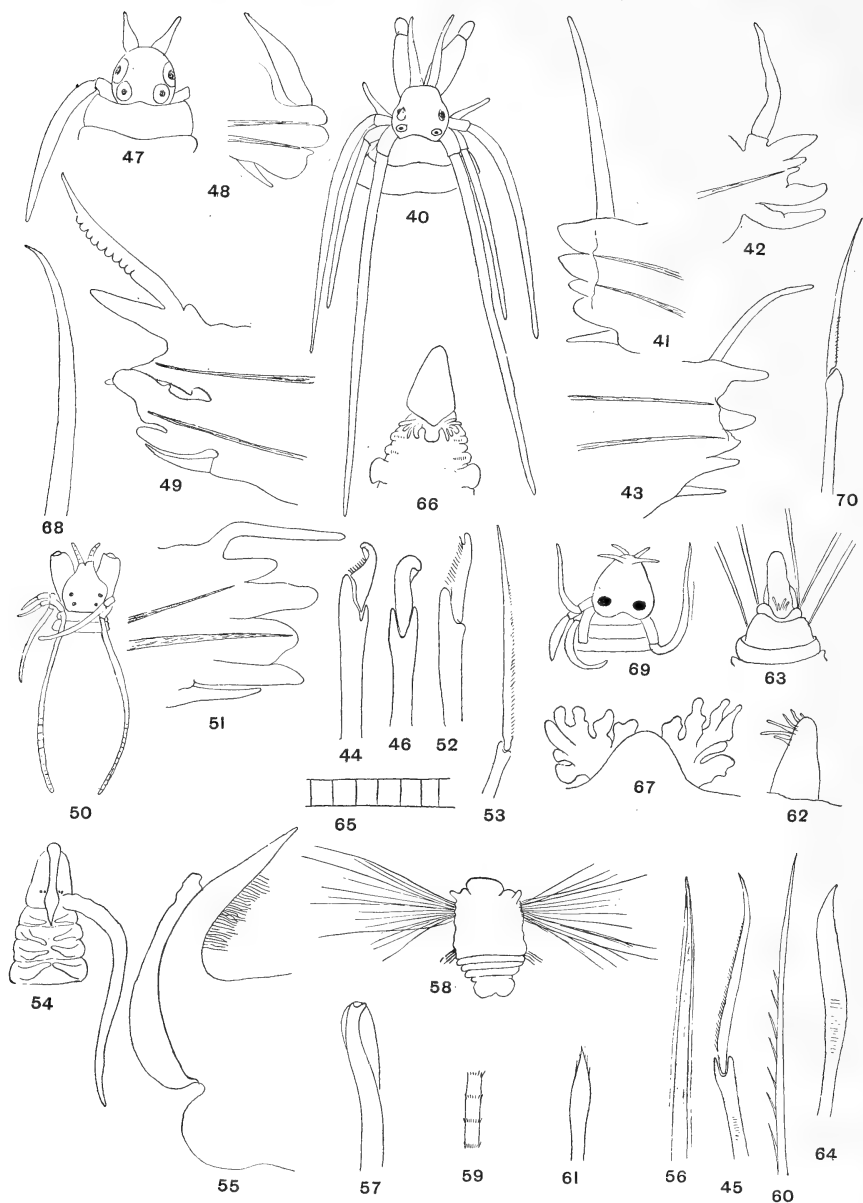


Fig. 179. 40, *Uncinereis lutea*, anterior end  $\times 16$ ; 41, 10th parapodium  $\times 45$ ; 42, 1st parapodium  $\times 45$ ; 43, parapodium from middle of body  $\times 45$ ; 44, seta from parapodium of fig. 43  $\times 250$ ; 45, 2nd form of setae from parapodium of fig. 43  $\times 250$ ; 46, compound seta  $\times 250$ ; 47, epitokous male  $\times 15$ ; 48, 7th parapodium of male  $\times 27.5$ ; 49, 17th parapodium of male  $\times 27.5$ ; 50, *Neanthes obscura*, anterior end  $\times 5$ ; 51, parapodium  $\times 45$ ; 52, ventral seta  $\times 250$ ; 53, dorsal seta  $\times 250$ ; 54, *Spio hirsuta*, anterior end  $\times 20$ ; 55, parapodium  $\times 45$ ; 56, anterior seta  $\times 250$ ; 57, posterior seta  $\times 250$ ; 58, spionid larva  $\times 15$ ; 59, detail of seta  $\times 45$ ; 60, end of seta  $\times 185$ ; 61, palea  $\times 250$ ; 62, *Semiodera glabra*, anterior end  $\times 10$ ; 63, ventral view of anterior end  $\times 10$ ; 64, notopodial hook  $\times 68$ ; 65, detail of seta  $\times 68$ ; 66, *Nuchubranchia palmata*, anterior end  $\times 10$ ; 67, gills  $\times 45$ ; 68, seta  $\times 100$ ; 69, *Phyllodoce varia*, anterior end  $\times 15$ ; 70, seta  $\times 250$ .

pairs). Chamberlin's *L. nans* (see above) shows this same distinction as to size but differs in that in this latter species three instead of two pairs of parapodia are thus modified. Absence of eyes is the only important distinction between the *Arcturus* specimens and Fauvel's description of *uncinatus* but as he states that the eye coloration may entirely disappear after preservation in formalin this difference is obviously of no importance. Fauvel records simple setae in the ventral part of the third parapodia. In the *Arcturus* specimens these occur also in the fourth. Two specimens collected at  $0^{\circ} 17' \text{ S.}$ ,  $91^{\circ} 34' \text{ W.}$ , at 300 fathoms. One immature animal probably the young of this species was taken at  $5^{\circ} 03' \text{ N.}$ ,  $81^{\circ} 08' \text{ W.}$ , in 250 metres.

#### Family NEREIDAE.

##### *Nereis* Cuvier.

##### *Nereis glandulata* Hoagland.

*Nereis glandulata* Hoagland, 1919, p. 575, pl. 30, figs. 1 to 6.

Four small and incomplete specimens were collected at  $17^{\circ} 39' \text{ N.}$ ,  $63^{\circ} 17' \text{ W.}$ , in 100 meters, and one at  $32^{\circ} 65' \text{ N.}$ ,  $65^{\circ} \text{ W.}$ , in 54 meters.

##### *Leptonereis* Kinberg.

##### *Leptonereis maculata* Kinberg.

*Nicon maculata* Kinberg, 1865, p. 178.

A considerable number of specimens of heteronereis which I have doubtfully identified as this species. They correspond to Kinberg's diagnosis as far as that goes but in common with many other taxonomists of his time, Kinberg's descriptions are too brief to allow of absolute certainty of identification. In his description there are no paragnaths on the pharynx, each jaw has seven teeth, the prostomium has an entire posterior margin, its anterior end is rounded but not narrowed, the antennae are longer than the palps and the longest tentacular cirrus extends to the seventh somite. With the exception that the antennae are about as long as the palps and the longest tentacular cirrus reaches to the eighth somite the *Arcturus* specimens correspond to this description.

All of the specimens are males, showing the characteristic modified anterior cirri. The change to the heteronereid type of parapodium comes at about the fiftieth somite. The animals vary in length from 35 to 100 mm. and in width from 1 to 3 mm. Large number, collected at  $0^{\circ} 27' \text{ N.}$ ,  $90^{\circ} 19' \text{ W.}$ , (Seymour Bay, Galapagos. 1 specimen, collected at  $0^{\circ} 19' \text{ N.}$ ,  $89^{\circ} 57' \text{ W.}$ , on the surface.

Kinberg (1865, p. 167) proposed the family Niconidea for nereids without paragnaths on the pharynx, and in this family he defined three genera depending on the character of the parapodia. Grube (1878, p. 62) rejected this subdivision, retaining the single genus *Leptonereis* for those nereids having no paragnaths.

##### *Uncinereis* Chamberlin.

##### *Uncinereis lutea*, sp. nov.

(Fig. 179: figs. 40 to 49.)

A small form, one cotype, a female with eggs, measuring 35 mm. in total length with a prostomial width of 0.75 mm. It has about 90 somites.



The most noticeable structural feature is the length of the postero-dorsal tentacular cirrus and of all dorsal parapodial cirri. In the preserving fluid the body often has a yellow color deepening into orange in some regions. The prostomial length is about equal to its width, being widest at the level of the anterior eyes, narrowing slightly in front of this. The eyes are very large and provided with lenses. The large size of the eyes is evidently correlated with the condition of sex development, since another specimen less than 10 mm. in length, and proportionately slender, has eyes relatively as large. The tentacles are longer than the prostomium, the palps not very stout, their rounded terminal joints extending slightly beyond the tentacles (figure 40). The postero-dorsal tentacular cirrus is stout and long, reaching to the 14th somite, the antero-dorsal is about two thirds as long as this and more slender, the postero-ventral a little shorter than the antero-dorsal, while the antero-ventral is very short, hardly reaching beyond the prostomium. All dorsal parapodial cirri are very long and slender. The female co-type retains one anal cirrus. This is very slender and is about 4 mm. long or two-thirds the length of the longest tentacular cirrus.

The tenth parapodium (figure 41) has a posterior lip which is nearly vertical, with slight protrusions where the aciculae reach the surface. There are two presetal notopodial lobes of which the dorsal is a trifle longer and more acute than the ventral. The cirrophore of the dorsal cirrus is about half way out on the dorsal lobe. There are two neuropodial lobes, the ventral being fully twice as wide as the dorsal but not quite as long. These four setal lobes are progressively shorter from above downward. The ventral cirrus is stout and extends beyond the setal lobe. The dorsal cirrus is fully four times as long as the setal lobe.

The first parapodium has only one setal lobe and acicula. Dorsal and ventral to the seta lobe are two prominent lobes. Just posterior to the apex of the acicula is a small lobe and between this and the dorsal lobe is a longer one reaching about half way to the apex of the latter. Both dorsal and ventral cirri are very prominent (figure 42).

A parapodium from near the middle of the body where the body wall is much distended with eggs (figure 43), has slender conical lobes, the space between the two notopodial ones being especially wide. The relative lengths of dorsal and ventral cirri remain about as they are farther forward.

In this last parapodium are three kinds of setae. Those of the neuropodium (figure 44) are all compound with a very short terminal joint. The apex of this is bent and is connected with the basal portion by a rod. The basal portion of this terminal joint is broad and apparently is provided with a row of slender spines along the margin although I was unable to find them in all cases. They are transparent and not easily seen and may have been broken in some of the setae. A second type of seta occurs as the dorsalmost of the neuropodial tuft and makes up nearly the entire notopodial seta bundle. In these the terminal joint is very long and sharp pointed and has a marginal row of spines (figure 45).

In all except the anterior region of the body a third type of compound seta occurs. The terminal joint is thickened and dark colored, the bent end con-

nected by a rod with the main portion (figure 46). There is thus a general resemblance to the type first described but they are much heavier and darker in color and have no marginal spines. I was unwilling to mutilate the type enough to determine exactly the distribution of these setae in it, but in a specimen of about one third the length of the type they begin on setigerous somite 16, and extend to the posterior end of the body.

Most of the specimens are immature but one mature male is described as a co-type with the female. This is in the epitokous phase. It is much smaller than the female measuring only about 13 mm. in length but has about the same number of somites. The prostomium (figure 47) is nearly circular in outline and the eyes are large. The tentacles are stouter than in the female but the palps are alike in the two sexes. Most of the tentacular cirri are lost.

The anterior parapodia have rounded lobes and the dorsal cirrus is much swollen. In the first this dorsal cirrus is hardly longer than the setal portion and is short-lanceolate in outline. In successive later somites this enlarges until in the 7th setigerous somite it has the form shown in figure 48. The setal lobes are three in number, very bluntly rounded at the ends and there is a very short, sharp pointed lobe at the end of the ventral acicula. The ventral cirrus is inconspicuous. Parapodia 8 and 9 have the blunt setal lobes but the dorsal cirri are slender though prominent. Beginning with the 10th parapodium there is an abrupt change in the form of the setal lobes which are sharp pointed. The dorsal cirri are at first simply long and slender but on setigerous somite 17 they assume a marginal lobing. The setal lobes are also modified (figure 49).

No modification of seta structure was to be found. Anterior somites have the same kinds of setae as those already described for the female. In the parapodium drawn in figure 43 there was one hook of the type shown in figure 44 and one compound seta like figure 45 with the long terminal joint. Both forms of the ordinary compound setae occur in the neuropodium.

Chamberlin (1919, p. 215, 216), proposed the generic name *Uncinereis* to include those nereids possessing stout crotchets in all parapodia except the most anterior; and having rounded anterior parapodial lobes. All specimens hitherto described were collected in the Pacific. The Arcturus specimens were collected at 26° 10' north latitude; 56° west longitude, on Sargassum.

Chamberlin does not specify the arrangement of the paragnaths except to say that they resemble those of *Platynereis*. In this genus groups I, II, V and some times VI, VII, and VIII are lacking. The paragnath arrangement is considered to be constant in the nereids, a point of much practical importance in taxonomy where the assumption of the epitokous phase may so greatly modify the appearance of the body in other respects. In none of these specimens was the pharynx protruded and because of their small size it is difficult to determine paragnath arrangement by dissection. So far as I could tell groups I and II are absent, III is in the form of long and short diagonally arranged rows, IV is absent, V is a single minute point, VI and VII are transversely arranged rows of very minute units, VIII is absent.

A second bottle from the same locality contained some very immature specimens characterized by dark parapodial glands and transverse dusting of minute specks on the peristomium.

*Neanthes* Kinberg.

*Neanthes obscura*, sp. nov.

(Fig. 179: figs. 50 to 53.)

A single entire specimen 35 mm. long and 1 mm. wide, collected at 5° 32' N., 86° 59' W.

The prostomium (figure 50), is broad at the base and very decidedly narrower between the palps. The antennae are separate at their bases and extend slightly beyond the bases of the palps. The palps have very stout basal portions and the terminal portion is a mere rounded nodule at the end of the basal. The eyes are small and in the preserved material are colored brown. Those of the same side are separated from one another by a distance equal to about twice their diameter, the anterior pair rather more widely separated. Antennae and cirri show traces of articulations.

In length the peristomium is about equal to the first somite. Apparently it is somewhat longer ventrally than dorsally but of this I am uncertain since it is distorted by the partially protruded pharynx. The paragnaths are I, 2 in a row; II, 6 to 8 in a transverse patch, the middle of the patch composed of double rows, the ends single teeth; III and IV, patches much like II with a single tooth on either side between III and IV; V, 3 conical teeth; VI, an oval patch on either side; VII and VIII, a continuous triple row, the distal row separated by a considerable distance from the other two and containing fewer teeth.

The tentacular cirri are all slender and show faint articulations toward the ends. The postero-dorsal ones are the longest, reaching to somite 8, the antero-dorsal ones not more than one third as long as these, both ventral ones very much shorter.

There is a single pair of anal cirri faintly articulated toward the ends.

A parapodium from the anterior region is shown (figure 51). The dorsal lip of the notopodium is shorter than the ventral, and a very small tuft of setae arises between the two, just dorsal to the position of the dorsal acicula. The neuropodium is rounded at the ends, the setae arising between anterior and posterior lips. The ventral lobe of the neuropodium is longer than the setae. The dorsal cirrus is slender and extends beyond the parapodium as far as the ends of the basal joint of the setae. The ventral cirrus is rather stouter than the dorsal and is shorter than the setal lobe. The ventral acicula is much heavier than the dorsal.

There are two kinds of setae. Those of the notopodial tuft and the dorsal-most of the neuropodial have slender basal joints and long slender sharp-pointed terminal ones, toothed along one edge (figure 53). The greater part of the neuropodial tuft is composed of much stouter compound setae whose terminal joint is slender as compared with the basal, its apex rounded and a row of slender spikes along one margin (figure 52). The terminal one or two of these are heavier than any of the others.

The type is in the collections of the New York Zoological Society.

*Ceratonereis* sp.

A fragment of the anterior end of a species of this genus was collected at 17° 39' N., 63° 17' W. The prostomium is very broad and the palps stout, though not especially long. The antennae and tentacular cirri are very slender. The jaws have 4 basal teeth with a smooth toothless portion between the terminal one of these and the apex. Group I of the paragnaths is absent; II obliquely arranged oval patches of about 14 rounded dark brown teeth; III, similar to II; IV, about 4 teeth. The basal joint of the pharynx is without paragnaths.

## Family HESIONIDAE.

*Hesione* Savigny.*Hesione proctochona* Schmarda.

*Hesione proctochona* Schmarda, 1861, p. 79, pl. 28, fig. 226.

One specimen collected at 17° 39' N., 63° 17' W., at 100 meters. Two other very small specimens undoubtedly of this species had not yet acquired the coloration of the adult. These were taken at 0° 16' S, 91° 23' W.

## Familt GLYCERIDAE.

*Glycera* Savigny.*Glycera abbranchiata* Treadwell.

*Glycera abbranchiata* Treadwell, 1901, pp. 200, 201, fig. 49.

Two small and much mutilated specimens. In neither is the head sufficiently well preserved to be of any use for identification. I have provisionally located them in this species because the parapodia and setae agree with the original diagnosis.

Collected at 17° 39' N., 63° 17' W., at 100 meters.

*Glycera dibranchiata* Ehlers.

*Glycera dibranchiata* Ehlers, 1864-68, pp. 670 to 702, pl. 24, figs. 1, 10 to 30, 32, 34.

Ehlers describes one specimen which had lost its posterior end as 210 mm. long and 8.5 mm. wide in the anterior region. The specimen I have is only 1.5 mm. wide. Regarding this size difference as due to immaturity of the *Arcturus* specimen I have listed this as a young individual of this species. The prostomium has only about six rings instead of the twelve or thirteen of Ehlers' diagnosis, there are compound setae in the notopodial tuft and the gills are not visible in all somites. Collected at 39° 15' N., 72° 0' W., in 633 fathoms.

*Goniada* Aud. et Milne Edwards.

At the same locality as the *Glycera* mentioned above was found the anterior end of a species of *Goniada*. The prostomium is evidently not ringed and there are no eyes. The dorsum of some anterior somites is marked with a dense brown color.

## Family LEODICIDAE.

*Leodice* Savigny.*Leodice longisetis* Webster.

*Eunice longisetis* (Webster), 1884, p. 317, pl. 10, figs. 46 to 49.

*Leodice longisetis* Treadwell, 1921, pp. 27 to 30, pl. 2, figs. 5 to 8, text figs. 54 to 65.

Several specimens collected at 17° 39' N., 63° 17' W., at 100 meters and at 125 fathoms.

*Leodice cariboea* Grube.

*Eunice cariboea* (Grube), 1856, p. 57.

*Leodice cariboea* Treadwell, 1921, pp. 47 to 49, pl. 4, figs. 1 to 4, text figs. 136 to 143.

Several specimens collected at 17° 39' N., 63° 17' W., at 100 meters. With these is one very small specimen which has no gills and at first was taken for a species of *Nicidion*. From the jaw structure it is identified as *L. cariboea*, the absence of gills being due to immaturity. One fragment was collected at 32° N., 65° W., in 54 meters.

*Leodice mutilata* Webster.

*Eunice mutilata* (Webster), 1884, p. 315, pl. 9, figs. 36 to 40.

*Leodice mutilata* Treadwell, 1921, pp. 30 to 33, pl. 3, figs. 5 to 8, text figs. 66 to 76.

Several collected at 17° 39' N., 63° 17' W., in 100 meters.

*Leodice culebra* Treadwell.

*Leodice culebra* Treadwell, 1921, pp. 49 to 51, pl. 2, figs. 13 to 16, text figures 144 to 153.

One specimen collected at Saba Bank, 17° 39' N., 63° 17' W.

*Leodice guanica* Treadwell.

*Leodice guanica* Treadwell, 1921, pp. 39, 40, pl. 2, figs. 9 to 12, text figures 107 to 116.

A single incomplete specimen conforming to the description of this species in general form of body and jaw apparatus, but I was unable to find any of the bifid form of acicula. Collected at 17° 39' N., 63° 17' W.

*Leodice longicirrata* Webster.

*Eunice longicirrata* (Webster), 1884, p. 318, pl. 12, figs. 75 to 80.

*Leodice longicirrata* Treadwell, 1921, pp. 11 to 14, pl. 1, figs. 1 to 4, text figs. 3 to 12.

A few small specimens collected at 17° 39' N., 63° 17' W., in 100 meters.

*Leodice fucata* Ehlers.

*Eunice fucata* (Ehlers), 1887, p. 91, pl. 25, figs. 1 to 20.

*Leodice fucata* Treadwell, 1921, pp. 43 to 47, pl. 4, figs. 5 to 10; text figs. 127 to 135.

Three specimens collected at 17° 39' N., in 100 meters. Two are labeled

as taken at longitude 63° 16' W., and one at 63° 17' W. I am uncertain if this is an error in recording or if two hauls were made so close together.

*Leodice unifrons* Verrill.

*Leodice unifrons* Verrill, 1900, p. 644.

*Leodice unifrons* Treadwell, 1921, pp. 17 to 20, pl. 1, figs. 5 to 9, text figs. 21 to 30.

One sexually mature female, collected at 39° 15' N., 72° W., in 633 fathoms.

*Leodice antennata* Savigny.

*Eunice antennata* (Savigny), 1820, p. 5.

Three specimens, the largest not over 15 mm. long. They are referred to this species because of the articulated tentacles and cirri, the trifid apex of the ventral acicula and the peculiar arrangement of gills. Typically, the gill arrangement is that they begin to appear as early as the 2nd setigerous somite, and extend to the posterior end of the body, being absent from only a few of the most posterior somites. In anterior regions the gill branches are as many as 6, in the median region there are not more than 2, posterior as many as 4. The only points in which these from the Arcturus collections differ from this typical condition is that the gills are absent throughout the median region and anteriorly and posteriorly the number of branches is less than the regular number. Since these are very much smaller than the full grown animals this seems to be merely a matter of maturity. Collected at 0° 19' N., 89° 51' W.

This species was described by Fauvel from Australia (1917, pp. 225 to 228, text figs. 20a, 20b) by Crossland from Zanzibar (1904, pp. 312 to 318, pl. 22, figs. 1 to 7, text figs. 56 to 60) and by Treadwell from Samoa (1922, p. 136). It seems probable that *Eunice interrupta*, described by Treadwell from Hawaii (1906, pp. 1167, 68, text figs. 45, 46) is really this species. Unfortunately the character of the ventral acicula which seems to be constant in specimens of all sizes, is not mentioned in this latter paper.

*Leodice floridana* Pourtales ?.

*Marphysa floridana* (Pourtales), 1863-69, p. 108.

*Eunice floridana* Ehlers, 1887, pp. 88 to 90, pl. 22, figs. 1 to 7.

A fragment of the posterior end of a leodid, which in the form of the gills, setae and anal cirri, approaches more nearly than any previously described species to this one of Pourtales, and I have tentatively listed it here.

Collected at 17° 39' N., 63° 17' W., in 100 meters.

*Leodice arcturi*, sp. nov.

(Fig. 178: figs. 32 to 39.)

A single complete specimen approximately 80 mm. long, its prostomial width 2 mm. Its most noticeable feature is the large size of the tentacles of which the unpaired is relatively heavy and extends to setigerous somite 12. The inner pair are about one sixth shorter than this, the outer pair two thirds the length of the inner. In a final transfer these tentacles were broken off and are now in the bottle with the type.

The prostomium (figure 32) is rounded, with only a very small median notch and no trace dorsally of a quadripartite lobing. The eyes are black. The second somite is about one-third as long as the first, the nuchal cirri extending beyond the bases of the tentacles. Succeeding somites are only a very little longer and wider than these, but there is an increase in size toward the middle of the body, narrowing at the pygidium to about one quarter of the anterior width. The specimen retains one slender anal cirrus.

The gills begin as two branches on the right side of the sixth parapodium and as four on the left side of the seventh and disappear entirely in the region of the forty-second parapodium. The number of branches increases rapidly, the tenth parapodial gill having eight branches and there are fourteen on the eighteenth.

The first parapodium has the form usual in this genus, a large dorsal and ventral cirrus, with a small setal lobe between. In later somites the dorsal cirrus remains long but becomes slender while the ventral cirrus is reduced to a small conical protuberance on the end of the rounded basal lobe of the parapodium. In the single specimen at my disposal this basal lobe is much swollen and more or less decomposed throughout the anterior region, and its structure difficult to see. Figure 33, of the twenty-fifth parapodium represents it as accurately as is possible. This parapodium carries a gill with fourteen branches some of which are broken, and a large dorsal cirrus. The setal lobe has a rounded postsetal lip, the anterior lip being shorter and vertical. There is a large pigment spot at the base of the gill.

Behind the gill region the parapodia become more nearly conical in outline and the ventral cirrus relatively more prominent. Figure 34 is of a parapodium taken from near the posterior end of the body. The slender dorsal cirrus is longer than the setal lobe and the apex of the ventral cirrus extends beyond this lobe.

Anterior parapodia have two aciculae, posterior ones have three, all noticeable on account of their large size. The dorsal ones are bluntly rounded at the end (figure 35), the ventral one hooked (figure 36). The compound setae are of the usual type, the terminal joint having apical and subapical teeth. Those from anterior somites have a more slender terminal joint than appears in posterior somites. Compare figure 37 with figure 38, the former from an anterior somite, the latter from a posterior. The simple setae are slender with scarcely a trace of lateral "fins."

The pectinate setae are few in number in each tuft. They have about ten teeth the terminal ones being longer than the others and unequal, that on one end being twice as long as that on the other.

The maxilla has in general a light brown tint, with the bases of the carrier, the inner margins of the forceps and the ends of the teeth a darker brown. There is also a dark patch where the forceps joins the carrier. The carrier (figure 39) is unusually long and narrow in proportion to its breadth, the forceps gently curved and long. The proximal paired plates have each seven teeth, the unpaired seven, the right paired eight, the unpaired three. The mandible was injured and I was unable to get an adequate description. It is slender and the thin beveled region is marked with concentric brown lines.

The type was collected at 39° 15' N., 72° W., in 633 fathoms. It is in the collections of the New York Zoological Society.

*Nicidion* Kinberg.

*Nicidion kinbergii* Webster.

*Nicidion kinbergii* Webster, 1884, p. 320, pl. 12, figs. 81 to 88.

*Nicidion kinbergii* Treadwell, 1921, pp. 91 to 93, pl. 6, figs. 5 to 8, text figs. 324 to 332.

Several, collected at 100 D. 1.

*Lysidice* Savigny.

*Lysidice notata* Ehlers, 1887, p. 100, pl. 30, figs. 1 to 9.

*Lysidice notata* Treadwell, 1921, pp. 86 to 88, pl. 8, figs. 1 to 4, text figs. 305 to 313.

Two specimens collected at 17° 39' N., 63° 17' W.

*Lysidice sulcata* Treadwell.

*Lysidice sulcata* Treadwell, 1901, p. 200, figs. 47, 47a, 48.

*Lysidice sulcata* Treadwell, 1921, pp. 89, 90, pl. 4, figs. 13 to 15, text figs. 314 to 323.

Three specimens collected at 17° 39' N., 63° 17' W., in 100 meters.

*Arabella* Grube.

*Arabella dubia* Treadwell.

*Arabella dubia* Treadwell, 1922, pp. 160 to 161, pl. 7, figs. 11, 12, pl. 8, figs. 8, 9, text fig. 52.

Two small specimens collected at 1° 22' S., 89° 39' W.

*Oenone* Savigny.

*Oenone diphyllidia* Schmarda (Not Ehlers).

*Oenone diphyllidia* Schmarda, 1861, p. 120, pl. 22, fig. 256.

*Aglaurides diphyllidia* (Treadwell), 1921, p. 116 to 119, pl. 7, figs. 13 to 16, text figs. 429 to 434.

Seven specimens collected at 17° 39' N., 63° 17' W.

Family ARICIIDAE.

*Scoloplos* Blainville.

*Scoloplos grubei* Gravier.

*Scoloplos grubei*, Gravier, 1909, pp. C114 to C116, pl. 5, figs. 49 to 55; pl. 6, figs. 60, 61 (paging of reprint).

Gravier's entire specimen was 48 mm. long. These are about 15 mm. In structure of prostomium, pharynx and setae the two agree. They differ in that acicular setae are found in twelve instead of seventeen anterior parapodia and that gills begin at about the thirteenth somite instead of the seventh. The differences seem to me to be due entirely to age, these being evidently much younger than the specimens from Peru. The locality label in the bottle reads "Hood, fd. 54."



## Family SPIONIDAE.

*Spio* (Fabricius) Oersted.*Spio hirsuta*, sp. nov.

(Fig. 179: figs. 54 to 57.)

The material consists of two portions of anterior regions and a fragment from a posterior region. This fragment is very much wider than either of the other pieces and I am not certain that it belongs to either of them. It is possible that this is the case since the appearance of one of the anterior fragments indicates that the body widens posteriorly. I have not, however, assumed this in the following description.

The prostomium (figure 54) is bluntly rounded, the peristomium fitting closely against the sides so that the whole head region has a conical outline. There is a gradual increase in diameter up to about the fifteenth somite, and behind this a narrowing extending to the fortieth. The region in front of somite forty has a compact, "well groomed" appearance, with its regular arrangement of parapodia and dorsal gills. Behind somite forty the appearance is more irregular. This effect is in part produced by the tufts of long white notopodial setae, which first appear at about somite forty-five and (in preserved material) stand at all sorts of angles with the body axis. Beginning in somite thirty-seven a similar tuft of white setae appears in the neuropodium. These are much shorter than the notopodial but are similarly colored and the two cooperate in making a visible distinction between the two regions of the body. The length of the first eighty somites in one specimen is 18 mm., the prostomial width is 0.5 mm.

The anterior end of the prostomium is rounded (figure 54) and the end expands so as to lie anterior to the corresponding portion of the peristomium. The prostomium narrows at the margin of the peristomium, widens again at the level of the eyes and terminates posteriorly in a point which extends over the dorsal surface of the first setigerous somite. Two eyes on either side are arranged in a transverse row. The peristomium seen from above gives the impression of a flattened plate whose margins are folded up to join the lateral margins of the prostomium. In each of the two specimens only one tentacle remains. This is heavy at the base but narrow at the apex and extends as far as the twelfth setigerous somite. In preserved material it is much coiled. In order to show its length it is drawn in figure 54, as it appears when straightened. On a ventral view the knob-like end of the prostomium terminates the head region, the peristomium fitting closely behind this and is no wider than it. The outline of the prostomium is that of a broad cone. A continuation of the median ventral band of the body extends to its end, and a fine white line on either side (nerve commissure ?) runs from the mid-ventral line in an antero-lateral direction around the peristomium.

The setal portion of the anterior parapodia (figure 55 of the fifteenth) extends but little from the general body surface but post-setal vertical lobes are very prominent. In the neuropodium these are evenly rounded in outline and not quite a half circle in area. In the notopodium the ventrally directed margin

of these lobes is quite similar in form to the dorsal margin of the ventral lobe from which it is separated by a narrow interval, while dorsally the lobe is continued as a narrow marginal "fin" on the outer edge of the gill extending two-thirds of the length of the latter. The gill is broad at the base but soon narrows to about one-half the basal width and is continued of uniform width until near the end when it shades off into an acute point. Its concave inner margin from the surface of the body to the point near the end where it narrows, is covered with a dense mass of fine hair-like processes equal in length to about one-half the diameter of the gill (figure 55). The gill extends dorsally as far as the mid line of the body. Since when seen from above the outlines of the gills are triangular, narrowing decidedly from base to apex, they leave uncovered a large part of the dorsal body surface. The gill is apparently the modified dorsal cirrus. I could find no trace of a ventral cirrus or of aciculae.

The anterior setae are rather stout, bilimbate and very sharp pointed, arranged in each tuft in a vertical row. Each (figure 56), is straight, sharp pointed and bilimbate. Beginning in one specimen on the twenty-eighth setigerous somite, and extending as far as the end of the fragment the neuro- and notopodium each has a tuft of hooded setae (figure 57). These are present in the anterior portion but absent from the posterior portion, of the fragment of a posterior end. Apparently they occur only in the median body region.

Collected at 5° 32' N., 86° 59' W. The type is in the collection of the New York Zoological Society.

Spionid larva, Gen. ? sp. ?

(Fig. 179: *figs.* 58 to 61.)

Surface collecting at 0° 05' South latitude; 91° 11' West longitude, yielded a single larva, evidently of a spionid. It is about 1 mm. long (figure 58), the body rather stout. Posteriorly there is a clear indication of three somites beside the pygidium, but the preservation is too poor to make it possible to determine the details with any accuracy. Anteriorly on either side is a short stumpy cirrus, and postero-ventral to this a tuft of 20 or more setae. Basally the shaft of each of these is banded at regular intervals with a row of short spines giving the shaft an articulated appearance (figure 59). Toward the end these spines are replaced by a double row of larger spiny plates. (Lateral view shown in figure 60.) These setae vary greatly in length, the longest exceeding the transverse body diameter. On either side, toward the posterior end, is a small tuft of a few flattened paleae (figure 61). The one drawn was slightly frayed at the end. This was probably accidental.

Family FLABELLIGERIDAE.

*Semiodera* Chamberlin.

*Semiodera glabra*, sp. nov.

(Fig 179: *figs.* 62 to 65.)

The type which is more than twice as long as any other in the collection, is 30 mm. long. At the prostomium it is barely 1.5 mm. wide but enlarges to a

width of 4 mm. in the region of the fifteenth somite, from which it again narrows to a width of about 2 mm. at setigerous somite twenty-seven. This latter width is continued practically unchanged for about twenty somites more, the anal somite being slightly narrower. Other specimens have essentially this form, but are somewhat narrower.

The surface of the body has a gray color due to a deposit of a translucent secretion which is more or less incrustated with fine sand grains. Underneath this the body surface under low magnification appears smooth, but if examined with a magnification of seventy to one hundred diameters numerous fine "cilia" are seen covering the entire surface.

In most specimens the prostomial region is retracted and nothing of interest can be said concerning it. In the type a formless mass protrudes from the mouth and dorsal to this is a rounded lobe longer than the prostomium, and with rounded ends. This carries a few short cirri on its margin (figure 62). In others the margin has a row of longer cirri. This is quite similar in appearance to fig. 7, pl. 42 of *Siphonostomum cariboeum* Grube, given in Ehlers (1887). Figure 63 is drawn from the anterior ventral surface of a specimen much smaller than the type, and shows the form of the gill-bearing lobe and its relation to the mouth. At the base are a few cirrus-like tentacles but these are only partially protruded and their relations are not clear. The figure also shows a ventral view of the first three somites. These narrow toward the prostomium but retain their circular outline in cross section, never becoming flattened on any surface. No specimen showed the palp (or tentacle) structure.

The first three sets of dorsal setae are elongated and extend in front of the prostomium forming the characteristic "cage." The ventral setae of the first two somites cooperate in forming this cage, while the third neuropodial ones are shorter and evidently do not. Beginning with the fourth setigerous somite and continuing posteriorly the notopodial setae retain their capillary character while those of the neuropodium are hooked (figure 64). Behind the third seta tuft the notopodial setae decrease in size, the length remaining constant throughout the greater part of the body. They are sharp pointed at the apices and the stalks have the articulated structure characteristic of this family. This is a true articulation and not merely a surface marking since the plane of division is visible at all focal points when examined under high power objective (figure 65). 18 specimens collected at 1° 22' S., 89° 39' W., in 15 ft. Apparently the type specimen is the only adult the others all being very much smaller.

The genera of this family are much confused. Chamberlin 1919, p. 397, proposed the new generic name *Semiodera* with *Siphonostomum cariboeum* Grube as the genotype. *S. glabra* seems closely related to this genotype but differs from it in the relatively slight development of the dermal papillae.

#### *Stylarioides* sp.?

In the same bottle with *Semiodera glabra* were a number of other specimens of this same family, the largest not more than 15 mm. long. The body tapers very slightly toward the anterior end, which is obliquely truncated so that it bears a dorso-anteriorly directed flat rounded plate. About midway of its

length the body abruptly narrows to less than half its anterior width and is continued in this diameter to the posterior end. There is a very fine incrustation over most of the body with a denser one, carrying a larger amount of sand, over the cephalic plate. A single tuft of long setae extending to a long distance beyond the prostomium, arises on either side of the ventral end of the cephalic plate.

Beginning with somite 2, slender notopodial and hooked neuropodial setae occur in each somite. The hooked setae are like those of *Semiodera glabra*. In one specimen a lobe, occupying a position like the tentacular lobe of *S. glabra* was protruded from the mouth, but there were no tentacles.

From the small size of these animals I infer that they are very immature specimens and since the gills, an important feature of the taxonomy, are not present, it seems unwise to do more than record the above details.

#### Family MALDANIDAE.

##### *Maldanids*, Gen. and sp.?

In a bottle marked 53D2 are tubes and portions of anterior ends of a number of maldanids, but because of poor preservation of the anterior ends and entire absence of the posterior regions I am unable to determine with certainty even the genera.

#### Family SABELLARIIDAE.

##### *Idanthyrsus* Kinberg.

##### *Idanthyrsus cretus* Chamberlin.

*Idanthyrsus cretus* Chamberlin, 1919, pp. 485 to 487, pl. 75, figs. 8 to 15.

Two specimens one of which is 12 mm. long and lacks the greater part of the abdominal region. In the following particulars, none of which are of specific importance, it differs from Chamberlin's description. There are two dorsal hooks on the right side, the branches of the pinnate paleae are equal instead of unequal and the dorsal thoracic paleae seem symmetrical at the ends though on account of imperfect preservation I could not be certain on this point. I did not find any stout tapering setae in the thoracic notopodia, but did find in both neuro- and notopodia very slender pinnate setae in general form like the marginal opercular setae but extremely slender.

Collected at Tagos Cove, Galpagos, at 1° 16' S., 91° 23' W.

#### Family OPHELIIDAE.

##### *Nuchubranchia*, gen. nov.

The body is fusiform, like *Ammotrypane* in general outline, without eyes or ventral furrow. Anal somite simple, margins of terminal orifice faintly scalloped. One pair of gills, dorsal to torus on the first somite.

Genotype *Nuchubranchia palmata*. In collections of the New York Zoological Society.

##### *Nuchubranchia palmata*, gen. et sp. nov.

(Fig 179: figs. 66 to 68.)

The type is 23 mm. long, 3 mm. at widest point and has twenty-one pairs of parapodia. The body is widest at the middle, tapering in both directions from there, the anal somite being wider than the prostomium.

The prostomium is bluntly conical in outline, about 1 mm. wide in its greatest diameter. The base is slightly narrowed and in the type the posterodorsal margin has the form of a blunt point (figure 66). This seems to have been due to the preservation, since it does not show in other specimens. Attached to the posterior margin of the prostomium is a rounded flap protruding posteriorly over the dorsal surface of the first somite. Immediately behind this is on either side, a flat plate with indented margins. This I at first thought was a protruded nuchal organ but it is located on the first somite and is evidently a gill. Figure 67 shows the appearance of the two gills and the flap as seen from in front after removal of the prostomium. Ventral to each gill is a vertical row of setae carried in a very slight swelling. Setigerous somite 2 has a similar torus with its vertical row of setae. In setigerous somite 3 the parapodium is distinctly divided into a dorsal and a ventral rounded elevation the setae arising from a short conical lobe lying half way between the two. Most of the setae are broken. Entire ones are curved and sharp pointed at the end with smooth margins (figure 68).

Collected at 0° 10' N., 88° 22' W., in 400 fathoms, 2 specimens; 0° 17' S., 91° 34' W., 20 specimens; 4° 50' N., 87° W., in 500 fathoms, 1 specimen; 4° 52' N., 84° 42' W., in 600 fathoms, 2 specimens. Sta. 282, 3 specimens; the type at 0° 00' Lat., 91° 53' W. and is in the collection of the New York Zoological Society.

#### Family TERESELLIDAE.

##### *Terebella* Linnaeus.

##### *Terebella brunneo-comata* Ehlers.

*Terebella brunneo-comata* Ehlers, 1887, pp. 237 to 241, pl. 51, figs. 1 to 5.

One specimen collected at 17° 39' N., 63° 17' W., in 100 meters.

##### *Loimia* Malmgren.

##### *Loimia bermudensis* Verrill.

*Loimia bermudensis* Verrill, 1900, pp. 595 to 670, pl. 70.

Verrill speaks of this as rather a stout species. I have listed with some hesitation, as this species, one collected at 17° 39' N., 63° 17' W., in 100 meters, though the specimen is rather slender. The structure of the mouth parts and the gills conforms to Verrill's description.

#### Family SABELLIDAE.

##### *Sabella* Linnaeus.

##### *Sabella melanostigma* Schmarda.

*Sabella melanostigma* Schmarda, 1861, p. 36, pl. 32, fig. 190.

A single specimen whose gills had been lost; in a mud tube. Collected at 17° 39' N., 63° 17' W.

## Family SERPULIDAE.

*Pomatostegus* Schmarda.*Pomatostegus stellatus* Abildgaard.*Terebella stellata* (Abildgaard), 1789, p. 142.

One specimen collected at 17° 39' N., 63° 16' W., in 130 meters.

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BY W. K. FISHER

*Director, Hopkins Marine Station of Stanford University*

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## SEA STARS\*

### FROM THE ARCTURUS OCEANOGRAPHIC EXPEDITION.

BY W. K. FISHER.

*Director, Hopkins Marine Station of Stanford University.*

Although the number of species brought back by the *Arcturus* was not large, a number of new distribution records were established. I am much indebted to Mr. William Beebe for the privilege of examining this material, a list of which follows:

#### Family PORCELLANASTERIDAE.

*Thoracaster magnus* Ludwig.

*Thoracaster magnus* Ludwig, *Zool. Anz.* vol. 31, 1907, p. 313; Clark, 1920, p. 78, pl. 1, fig. 1, 2.

Type in U. S. National Museum.

Station 53, D. 2, Lat.  $1^{\circ} 51'$  S., Long.  $89^{\circ} 50'$  W. (tropical eastern Pacific) 1733 fathoms, 1 specimen.

The known range of this species is from latitude  $1^{\circ} 51'$  to  $8^{\circ} 30'$  south and longitude  $85^{\circ} 19'$  to  $98^{\circ} 56'$  west. The type and 8 other specimens were dredged by the *Albatross* in from 2,005 to 2,370 fathoms, between latitude  $4^{\circ}$  and  $8^{\circ}$  south, mostly on globigerina ooze; bottom temperature  $35.2^{\circ}$  to  $35.5^{\circ}$  Fahr.

Thoracaster, like most other members of the archaic though highly specialized Porcellanasteridae feeds upon the mud in which it burrows. The stomach is large and simple, occupying the entire disk. There is no dorsal chamber of the stomach similar to that which is characteristic of most sea stars. Instead the dorsal wall is closely juxtaposed to the wall of the disk as in the Ophiuroidea. In sea stars the large central aperture (or actinostome) of the ventral skeleton of the disk is framed by 5 pairs of first ambulacral plates (radial in position) and 5 pairs of jaws (interradial in position). In Thoracaster the ambulacral elements are longer than I have noted in any other sea star and the whole frame is unusually flexible. Very probably fairly large objects such as molluscs and sea urchins can be ingested along with the ooze.

The stomach of the specimen contained, however, only mud—about 9 cc., which filled it. This mud is predominantly calcareous, consisting of foraminifera. Treatment with acid reveals several genera of diatoms and radiolaria, sponge spicules, a little volcanic dust (about the size of the diatoms), and flocculent organic material comprising perhaps 10% of the whole bulk. It is undoubtedly rich pabulum.

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\* Contribution, New York Zoological Society, Department of Tropical Research, No. 296.

## Family ASTROPECTINIDAE.

*Leptychaster inermis* (Ludwig).

*Parastropecten inermis* Ludwig 1905, p. 76; pl. 4, fig. 21, 22; pl. 21, fig. 117; pl. 22, fig. 126.

*Leptychaster inermis* Fisher 1911, p. 53; Clark 1913, p. 188.

Station 74. OT4, Lat. 4° 50' N., Long. 87° 00' W. (tropical eastern Pacific) 625 fathoms, 1 specimen (R 12 mm., r 6 mm., R=2 r.).

The other specimens are two dredged by the Albatross in 695 fathoms off Panama, on green mud, bottom temperature 39° Fahrenheit; 1 off Lower California, 645 fathoms; and 2 from off Monterey Bay, California, 659 to 871 fathoms.

The species is evidently a *Leptychaster* and is quite distinct from *L. anomalus* Fisher (Sea of Japan, Bering Sea, southern Alaska). The present specimen is a little more delicate than Ludwig's type, with relatively narrower marginals. In general form it resembles *L. propinquus* (Fisher, 1911, pl. 9, fig. 3) but of course has broader superomarginal plates. *Inermis* has 6 or 7 furrow spinelets; *anomalus* 3 or 4.

For a discussion of the generic position of *inermis* see Fisher 1911, p. 53. The practical difficulty of recognizing *Parastropecten* for the short-armed species of *Leptychaster* is here pointed out. Nevertheless Verrill later attempted to maintain two genera (1914, p. 328), although for *Parastropecten* he used *Glyphaster* Verrill, 1909. The generic diagnosis was probably based upon one specimen of *L. anomalus*, since it does not apply to some of the variants of *anomalus*, nor to *L. propinquus* or *L. inermis*.

*L. inermis* ranges from off Panama to Central California. In view of the capture of *inermis* off Monterey (Clark, 1913, p. 188), the tiny specimen of *anomalus* recorded by the writer from 871 fathoms off Monterey is probably referable to *inermis*.

*Dytaster gilberti demonstrans* Ludwig.

*Dytaster demonstrans* Ludwig, 1905, p. 41, pl. 5, fig. 23-25; pl. 18, fig. 97-99; pl. 19, fig. 107; pl. 20, fig. 108-115. Clark, 1920, p. 82.

Type in U. S. National Museum.

Station 53, D. 2, Lat. 1° 51' S., Long. 89° 50' W. (tropical eastern Pacific) 1733 fathoms, 6 specimens.

The known range of this species is from latitude 10° 14' north to 8° 30' south and from longitude 80° 21' to 96° 28' west. The bathymetrical range is 1322 to 2370 fathoms; temperature range 35.2° to 36.4° Fahrenheit.

There can be little doubt that the range of this form is continuous with that of *D. gilberti* Fisher from off San Diego, California, 2,196 to 2,228 fathoms. The range of variation of *gilberti* is not known, since only 2 specimens are in existence. In *demonstrans* the paxillar area is narrower and is evenly tapered from the base to end of ray whereas in *gilberti* (besides being broader) it is scarcely tapered at all for a third of the length of ray, and then rather more rapidly than in *demonstrans*. On the outer half of ray of *gilberti* the dorsal surface is conspicuously narrower than the ventral so that the marginal plates slope inward like a roof (Fisher, 1911, pl. 17, fig. 1.). In *demonstrans* the sides of the ray are nearly perpendic-

ular. The furrow comb consists of 11 or 12 spinelets; in *gilberti* of 10 (sometimes 8 or 9).

It seems to me likely that *gilberti* and *demonstrans* intergrade and that each is a race of a wide ranging abyssal species, for which the name *gilberti* has priority.

The Arcturus specimens were taken on foraminera mud along with *Thoracaster magnus*. Unfortunately the stomachs of all the specimens were washed clean.

*Psilaster florum* (Verrill).

*Archaster florum* Verrill, *Amer. Journ. Sci.*, vol. 16, 1878, p. 16.

*Psilaster florum* Verrill, *Proc. U. S. Nat. Mus.*, vol. 17, 1894, p. 255

Station 113, Lat. 39° 15' N., Long. 72° W. (western Atlantic), 633 fathoms, 1 specimen.

A long-known species probably, at best, a race of *Psilaster andromeda* of Europe.

*Astropecten americanus* (Verrill).

*Archaster americanus* Verrill, *Amer. Journ. Sci.*, vol. 20, 1880, p. 402.

*Astropecten americanus* Verrill, *Proc. U. S. Nat. Mus.*, vol. 17, 1894, p. 255; 1915, p. 184, pl. 6, fig. 1, 1a.

Station 113, Lat. 39° 15' N., Long. 72° W. (western Atlantic), 633 fathoms, 18 specimens.

Verrill (1915) regards this as the most abundant starfish off the Atlantic coast of the United States, if the littoral species of *Asterias* are excepted.

"It occurs abundantly from N. lat. 40° 23' to the region of the Carolina coasts. Farther south it seems to be less common, but it reaches the Florida Straits, West Florida, and the Caribbean Sea, off Colombia.

"It was most abundant in 60 to 150 fathoms, where 2000 to 5000 were repeatedly taken by us in a single haul of the trawl" (Verrill, 1915, p. 186). Verrill records 43 to 296 fathoms as the extreme range. The Arcturus specimens are recorded as from 633 fathoms.

Döderlein places this species in his *Articulatus* group, on the border between the *Articulatus* and *Brasiliensis* groups (1917, p. 106).

Family ODONTASTERIDAE.

*Odontaster hispidus* Verrill.

*Odontaster hispidus* Verrill, *Amer. Journ. Sci.*, vol. 20, 1880, p. 402; 1899, p. 206, pl. 29, fig. 3, 3a; 1915, p. 119, pl. 13, fig. 6.

Station 113, D. 1, Lat. 39° 15' N., Long. 72° W. (western Atlantic) 633 fathoms; 6 specimens.

Verrill (1915) says: "This species was taken by the U. S. Fish Commission at many localities from off Marthas Vineyard to Florida, in 43 to 480 fathoms and more."

The specimens upon which *Odontaster setosus* Verrill are based need very critical reexamination. It seems probable that *setosus* is a forma of *hispidus* as the two often occur together. Four of the 6 Arcturus specimens are referable to *setosus*, one to *hispidus* while one is intermediate.

## Family GONIASTERIDAE.

*Nymphaster diomedae* Ludwig.

*Nymphaster diomedae* Ludwig, 1905, p. 128, pl. 10, fig. 48, 49, 52, 53; pl. 11, fig. 54, 55.

Station 74, OT4, Lat. 4° 50' N., Long. 87° W. (tropical eastern Pacific south of Cocos), 625 fathoms, 1 specimen.

Ludwig records this species from four stations of the Albatross between 0° 04' south and 6° 35' north and 81° 44' and 90° 24' 30'' west (Galapagos, Gulf of Panama), in from 384 to 885 fathoms; temperature range 37.2° to 43.3° Fahrenheit, globigerina ooze, green, and gray sand.

## Family OREASTERIDAE.

*Nidorellia armata* Gray, 1840.

Two specimens without locality record. The species occurs from Ecuador to the Gulf of California.

## Family LINCKIIDAE.

*Ophidiaster guildingii* Gray.

*Ophidiaster guildingii* Gray, *Ann. Mag. Nat. Hist.*, 1840, p. 284.

Station 23, Lat. 17° 39' N., Long. 63° 16' W. (Saba Bank, Lesser Antilles), 2 specimens.

This is the West Indian equivalent of the Mediterranean *O. ophidianus*. Clark (1921, p. 79) states that the species ranges from the Tortugas to Tobago. The writer has collected it at Barbados and Antigua, well within this range.

## Family PORANIIDAE.

*Porania insignis* Verrill.

*Porania insignis* Verrill, *Amer. Journ. Sci.*, vol. 49, 1895, p. 138.

Station 113, D. 1, Lat. 39° 15' N., Long. 72° W. (east of Cape May), 633 fathoms, 6 specimens.

When taken from formalin these specimens were mottled orange red and Vandyke red.

In his original description Verrill records that this species was taken by the Albatross at numerous stations from latitude 41° 28' 30'' to 36° 38' 30'' (as well as on the "Banks" by Gloucester fisherman) in from 65 to 373 fathoms. The *Arcturus* record therefore greatly increases its bathymetrical range.

*Poraniella echinulata* (Perrier)

*Marginaster echinulatus* Perrier, *Bull. Mus. Comp. Zool.*, vol. 9, 1881, p. 17.

*Poraniella echinulata* Verrill, *Ann. Mag. Nat. Hist.*, vol. 14, 1914, p. 20; 1915 p. 73.

Station 23, Lat. 17° 39' N., Long. 63° 16' W. (Saba Bank), 1 specimen.

*Poraniella* is probably the young stage of an unknown adult. The present specimen has R 5. 75 mm. and resembles Verrill's figure of *P. regularis* (1915, pl. 7, figures 1, 1a), which seems to the writer to be but a variation of *echinulata* (figured by Perrier, 1884, pl. 1, fig. 6, 7).

## Family ECHINASTERIDAE.

*Henricia sanguinolenta* (Müller)

*Asterias sanguinolenta* O. F. Müller, *Zoologiae Danicae Prodrömus*, 1776, p. 234.

Station 113, D. 1, Lat. 39° 15' N., Long. 72° 00' W. (east of Cape May), 633 fathoms, 3 specimens.

These appear to represent a deep water variety of the widely distributed *sanguinolenta*, having unusually delicate abactinal spinelets and papular areas broader than the intervening spiculated ridges of the plates. R. 25 mm. r. 5.5. mm.

## Family MITHRODIIDAE.

*Mithrodia bradleyi* Verrill.

*Mithrodia bradleyi* Verrill, *Trans. Conn. Acad.*, vol. 1, 1869, p. 288.

Fisher, 1906, p. 1094, pl. 36, fig. 1, 2; pl. 37, fig. 1-3.

Chatham Bay, Hood Island, Galapagos Archipelago, 1 specimen. Known also from Lower California and Hawaiian Islands.

## Family ZOROASTERIDAE.

*Zoroaster ackleyi* Perrier.

*Zoroaster ackleyi* Perrier, 1884, p. 197, pl. 3, fig. 1.

Clark, 1920, 102.

Station 23, Lat. 17° 39' N., 63° 17' W. (Saba Bank, Lesser Antilles), 1 specimen, R 127 mm.

Off Pensacola, Florida, 525 fathoms to Montserrat 120 fathoms.

Clark gives a good key to the species of this genus.

## Family ASTERIIDAE.

*Coronaster briareus* (Verrill)

*Asterias briareus* Verrill, *Amer. Journ. Sci.*, vol. 23, 1882, p. 220.

*Coronaster briareus* Verrill, 1915, p. 31, pl. 1, fig. 1, 2; pl. 9, fig. 4-4c.

Station 113, D. 1, Lat. 39° 15', long. 72° 00' W. (east of Cape May), 633 fathoms.

Verrill, 1915, p. 32, states that the species was dredged by the *Albatross* at several stations in 31 to 373 fathoms between north latitude 37° 18' 11" and 36° 41' 05". The *Arcturus* specimen therefore furnishes the deepest and most northern record. It has been taken in 75 to 110 fathoms off Florida.

The unguiculate, hand-shaped, straight pedicellariae are rather scarce in the *Arcturus* specimen.

For a discussion of the relationships of this genus see Fisher, 1919, p. 494.

*Sclerasterias tanneri* (Verrill)

*Asterias tanneri* Verrill, *Amer. Journ. Sci.*, vol. 30, 1880, p. 401.

*Orthasterias tanneri* Verrill, 1914, p. 48, 168; pl. 48, fig. 6.

*Sclerasterias tanneri* Fisher, *Bull. l'Inst. Oceanographique*, No. 444, July 31, 1924, p. 4; *Bull. U. S. Nat. Mus.* 76, part 2, 1928, p. 107.



Station 111, D. 2, lat.  $38^{\circ} 00' N.$ , Long.  $74^{\circ} 02' W.$ , 382 fathoms, 1 specimen.

Station 113, D. 1, Lat.  $39^{\circ} 15' N.$ , Long.  $72^{\circ} 00' W.$ , 633 fathoms, 12 specimens, badly broken.

Verrill records this species as ranging from north latitude  $35^{\circ} 10'$  to  $40^{\circ} 08'$  and from 40 to 194 fathoms. The *Arcturus* specimens greatly increase the known bathymetrical range.

When taken from formalin the specimens retained apparently some of the natural coloration, being Vandyke red in general tint, the base of spines pinkish purple.

*Asterias vulgaris* Verrill.

*Asterias vulgaris* Verrill, *Proc. Boston Soc. Nat. Hist.*, vol. 10, 1866, p. 349.

Station 113, D. 1, lat.  $39^{\circ} 15' N.$ , long.  $72^{\circ} 00' W.$ , 633 fathoms, 1 specimen; (1 other specimen, locality doubtful).

In shallow water the species ranges from Labrador to the eastern part of Long Island Sound, while in deep water it continues on to the neighborhood of Cape Hatteras. The deepest record heretofore known is 358 fathoms.

*Asterias forbesi* (Desor).

*Asteracanthion forbesi* Desor, *Proc. Boston Soc. Nat. Hist.*, vol. 3, 1848, p. 67.

Station 109, D. 1, Lat.  $36^{\circ} 56' N.$ , Long.  $75^{\circ} 28' W.$ , 36 metres, 1 young specimen, R 18 mm.

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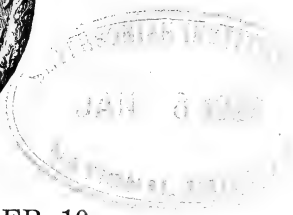


# ZOOLOGICA

## SCIENTIFIC CONTRIBUTIONS OF THE NEW YORK ZOOLOGICAL SOCIETY

DEPARTMENT OF TROPICAL RESEARCH  
ARCTURUS OCEANOGRAPHIC EXPEDITION

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VOLUME VIII. NUMBER 10

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### SCYPHOMEDUSAE FROM THE ARCTURUS OCEANOGRAPHIC EXPEDITION

By HENRY B. BIGELOW

*Museum Comparative Zoology  
Harvard University*

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## SCYPHOMEDUSAE \*

FROM THE ARCTURUS OCEANOGRAPHIC EXPEDITION.

BY HENRY B. BIGELOW.

*Museum of Comparative Zoology.*

(Figs. 180-184 incl.)

### SPECIES.

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### Order CORONATA.

Family PERIPHYLLIDAE.

Genus *Periphylla*.

I believe it probable that all the *Periphyllas* yet described will eventually prove nothing more than contraction-phases or racial variants of a single species, the cosmopolitan, but bathypelagic *P. hyacinthina*, Steenstrup. Recent studies (Bigelow 1909, 1913, Broch, 1913), and especially Broch's (1913) examination of the very large series collected by the *Michael Sars*, in the North Atlantic, have resulted in the definite union of *P. dodecabostrycha* with *P. hyacinthina*. Broch still retained Haeckel's name *regina* for a few of these specimens, in which the floor of the subumbrella was evenly rounded, with no trace of the so-called "stiel canal," and in which the pedalia were more globular, and less oval, than is usual among *P. hyacinthina*. But the present series contains two specimens precisely intermediate between *hyacinthina* and *regina* in these respects, for while they lack "stiel canal," their pedalia show the usual *hyacinthina* conformation; consequently the combination of characters used

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by Broch does not suffice to separate *regina* from *hyacinthina*. Final decision as to whether *regina* is, in fact, separable from *hyacinthina* in any other way can be reached only after larger series of specimens with the globular pedalia, supposedly characteristic of it, have been examined. The *Arcturus* series are all typical *hyacinthina* in this respect.

*Periphylla hyacinthina*, Steenstrup.

*Periphylla hyacinthina*, Steenstrup, 1837.

Synonymy, Mayer, 1910, p. 544-546 (incl. forma *dodecabostrycha*).

Station 7, 3000-0 meters, one fragmentary specimen; about 25 mm. in diameter.

Station 50, 1200-0 fathoms; one excellent specimen, about 40 mm. in diameter by 72 mm. high.

Station 59, 600-0 fathoms, 1 specimen, about 55 mm. in diameter.

Station 61, 600-0 fathoms, one about 20 mm. in diameter by about 20 mm. high, and fragments of another very large one.

Station 66, 600-0 fathoms, one about 95 mm. in diameter by 110 mm. high.

Station 68, 600-0 fathoms, fragments.

Station 74, 450-0 fathoms, one specimen, 17 mm. in diameter. 600-0 fathoms, 8 specimens, 17-85 mm. in diameter, and fragments of others. 749-0 fathoms, 2, fragmentary, about 40-50 mm. in diameter.

Station 84, 500-0 fathoms, 2, of 18 and 20 mm. diameter.

Station 100, 1098-0 meters, one specimen, about 30 mm. in diameter by 36 mm. high; 2192-4 meters, 3 specimens, 22-30 mm. in diameter.

Station 105, 500-1 fathoms, one, about 17 mm. in diameter.

Station 107, 700-1 fathoms, two, respectively 14 and 20 mm. in diameter.

Station 113, 800-0 fathoms, 1 specimen about 20 mm. in diameter, and 3 others of the following dimensions:—22 mm. diam. by 20 mm. high; 22 mm. diam. by 31 mm. high; 25 mm. diam. by 40 mm. high.

Also, 2 other specimens, unlabelled, one about 45, the other about 110 mm. in diameter.

The series illustrates various intermediates from specimens with the bell lower than broad, to others in which it is much higher than broad, as the listed measurements show. And one (station 50) is of very high, pointed outline. All but two show a stiel canal—longer or shorter. All specimens larger than about 35 mm. in diameter, and three of the small specimens, of 18, 20 and 22 mm., are typical *hyacinthina* in color, with the gonads entirely masked by the dense pigmentation. Most of those smaller than 30 mm. are of the *dodecabostrycha* type, in this respect, with only the central portion of the gastro-vascular system pigmented, so that the gonads show through, when viewed from without. And three specimens, of 17, 20, and 22 mm. respectively, are best described as intermediate in color, their gonads being partially concealed. On the whole, then, the *Arcturus* series shows an extension of the pigmentation with growth, corroborating earlier studies. But Broch (1913) has found that this progressive pigmentation is not only complicated by wide individual

variation, but also by a definite correlation between the amount of pigmentation and the depth at which the medusa lives; among the very extensive series collected by the *Michael Sars*, heavily pigmented specimens were most plentifully represented in hauls from 600 meters or deeper, the paler ones (*dodecabostrycha* type) in shoaler hauls.

The present series are all from hauls so deep that they throw no light on this question. The failure to take any in shoal hauls is, however, interesting, as further confirmation of the thesis that *Periphylla* never normally swims upward to the zone of strong illumination in Tropic seas, contrasting with its not exceptional occurrence right at the surface in arctic and subarctic latitudes (Kramp 1913, 1924).

Most of the *Arcturus* locality records are from the Gallapagos-Cocos I. region in the Tropical Pacific (Stations 50-84), where this medusa has already been found widespread (Maas, 1897, Bigelow, 1909). The rest are from the Atlantic:—Sargasso Sea to the southeast of Bermuda (Stations 7, 14); vicinity of Bermuda (station 100); and continental slope in the offings of Cape Hatteras (Station 107) and of New York (station 113). With previous records, these show *Periphylla* as cosmopolitan over the western Atlantic as it is in other parts of the ocean, and in the Mediterranean (Kramp, 1924, p. 40, Chart X).

#### Family NAUSITHOIDAE.

#### Genus *Nausithoë*.

As now recognized, the genus *Nausithoë* includes all those members of its family in which there are 8 tentacles and 8 sense organs; 16 marginal lappets; and 8 gonads primarily adradial, whether or not these organs approach one another in the interradii, or even coalesce, when mature.<sup>1</sup>

Recent authors have devoted considerable attention to *Nausithoë*; nevertheless it is not yet possible to determine how many true species are actually represented by the various forms which have been named. In part this is due to the paucity of specimens of the various bathypelagic *Nausithoës* which have yet been examined; but still more to the intergrading nature of the characters by which the several species are supposed to be separable. A final revision of the genus can not be expected until some one is able to study the range of variation of such characters as the sculpture of the exumbrella, the degree of pitting of the central disc, the shape of the marginal lappets, and the outline and size attained by the gonads at maturity.

As matters now stand, the known members of the genus fall into three subdivisions; the *punctata* group, characterized by the

<sup>1</sup> See Broch (1913) for a general survey of the limits of the genus.



presence of ocelli (with lens) and by gastric filaments in continuous series: the *rubra* group with the gastric filaments similarly arranged but lacking ocelli; and the *albatrossi* group, with the gastric filaments in clusters (it is not known whether *albatrossi* has ocelli).

In the first group, besides *N. punctata*, fall *N. Challengeri*, Haeckel, *N. picta*, Agassiz and Mayer, and *N. limpida*, Hartlaub, all of which may finally prove to be variants of the one species, *N. punctata*. *N. picta*, in fact, differs from *punctata* only in the progressive development of its gonads and in its more brilliant pigmentation. *N. challengeri* (2 specimens seen only) is separable from *N. punctata* only by the faint radial furrows which Haeckel records as marking the margin of its central disc, and by more prominent exumbrel sculpture, characters which have proved extremely variable in related medusae. And Hartlaub's (1907) *N. limpida* agrees in every respect with *punctata* of equal size, except that the median members of each group of gastric cirri arise from a centripetal, radial fold of the dorsal wall of the stomach.

The second group, includes *N. rubra*, *N. atlantica* and *N. globifera*. The interrelationships of the first two are discussed below (p. 500). All of the characters by which Broch (1913), separates *globifera* from *atlantica*, are relative: e. g. relative development of the gonads at different sizes; prominence of the exumbrellar sculpture; degree of arching of the bell; presence or absence of exumbrel nettle spots; precise length of the small lappets which bear the rhopalia; and pigmentation. Since most of these same characters have proved highly variable in the related genera *Periphylla* and *Atolla*, both of which also show wide individual variation in size of bell relative to stage of development of the gonads (perhaps depending on nutrition), it is not safe to assume greater stability for the bathypelagic members of *Nausithoë*. It therefore seems likely that *rubra*, *atlantica* and *globifera* will finally prove to represent extreme variants of the one species, though no definite pronouncement can be made until much larger series (and series in a better state of preservation) can be examined.

*Nausithoë punctata*, K  lliker.

*Nausitho   punctata*, K  lliker, 1852, p. 323.

Synonymy, see Bigelow, 1909, p. 35; Mayer, 1910, p. 554.)

A single specimen of this well-known species, about 5 mm. in diameter, was taken among the Gallapagos, Station 49, 1   39' S; 89   30' W; depth not stated.

This specimen (an adult with large gonads) is not in good enough condition to add anything to the previous accounts of this well known species. I may point out, however, that the gonads are all spherical, and equidistant, and that the gastric filaments of each bundle arise in a single straight row, these being two of the distinguishing characters of the species. The specimen is too much damaged to show the state of the exumbrellar warts.

*N. punctata* was to be expected in Gallapagos waters, having been recorded from off the west coast of Mexico; from the vicinity of Easter Island; from Japanese waters; at Tonga and Fiji in the west Tropical Pacific; and from various localities in the Indian Ocean (Agassiz and Mayer 1899, 1902; Browne, 1916; Bigelow 1904, 1909, 1913).

The south seas representative of the species was described as a distinct variety, *pacifica*, by Agassiz and Mayer. And this name is retained by Stiasny (1919) for specimens from the West and East Indies. But the supposed differences—slightly paler coloration and frequent absence of spots on the exumbrella in the var. *pacifica*—are so slight, and so variable, that my own examination of specimens from the Western Atlantic, West Indies, Mediterranean, Eastern Tropical Pacific, Fiji, Japan and the Maldives, gives no sound ground for distinguishing a Pacific or an Indian race of this wide ranging species, as distinguished from an Atlantic. Mayer (1910), too, and Browne (1916) recognize only the one race.

The range of *Nausithoe punctata* thus includes the tropical and subtropical belts of all three great oceans; also the Mediterranean.

*Nausithoe rubra* Vanhöffen.

*Nausithoe rubra*, Vanhöffen, 1902, p. 30, taf. 1, figs. 4, 5; Bigelow, 1909, p. 36, pl. 12, fig. 6.

?*Nausithoe atlantica*, Broch, 1913, p. 10, pl. 1, figs. 1-4.

One specimen, about 8 mm. in diameter, in fair condition; station 45, Lat. 0° 20' N.; Long. 90° 10' W., near the Gallapagos Is.

This specimen adds little, except in the way of confirmation, to the earlier accounts of the species (Vanhöffen, 1902; Bigelow 1909). It is, however, interesting as illustrating a more advanced stage in the growth of the gonads, and as affording an opportunity to test the validity of the characters by which Broch (1913) separated his *N. atlantica* from *N. rubra*.

Fortunately the rhopalia are in good enough condition to show that ocelli are lacking, as is characteristic of the species *rubra*, and of the other bathypelagic members of the genus (p. 498). The characteristic arrangement of the considerable number of gastric cirri (approximately 100) in a single continuous series, along the four sides of the stomach, is also easily traced.

In Vanhöffen's (1902, P. 30, Pl. 1, figs. 4, 5) original account and illustrations, the gonads are shown as spherical and equidistant; with large eggs.<sup>2</sup> The present example shows, however, that this is not the final state. Here the gonads are relatively much larger, and have so broadened at the base that they have not only taken on a roughly shield shape, but have come close together in the perradii as well as in the interradii. It is also interesting to find considerable variation in the shapes of the individual gonads in the single individual, for

<sup>2</sup> In the Eastern Pacific specimens (Bigelow 1909), the gonads were destroyed.

while seven are regularly shield shaped, and broadest at the proximal ends, one is much narrower, oval, and nearly twice as long as the rest. This specimen, like Vanhöffen's, is apparently a male, surface views of the gonads showing sperm-follicles in various stages of growth, from small to large, much as in Haeckels (1881) figures of *N. Challengeri*.

The *Michael Sars* series of *N. atlantica* illustrate a still more advanced state, for while the gonads (more or less shield shaped as in the present specimen) are separated by distinct spaces in the perradii, some of the pairs are in close contact in the interradii in adults (Broch 1913, Pl. 1, Fig. 2).

The marginal lappets corroborate Vanhöffen's account, by their great length, and narrow, pointed outlines. And each rhopalium is situated on a very short subsidiary lappet, at the bottom of the deep marginal notch which indents the margin, alternating with the tentacles. These small rhopalar lappets are also to be seen on Vanhöffen's beautiful pictures of *N. rubra*. Broch (1913) described corresponding structures as one of the distinguishing features of *N. atlantica*. But they are nearly as large in the present specimen as he shows them for *atlantica* (Broch, 1913, Pl. 1, Fig. 2); and only a little, if any larger than Vanhöffen shows them, in his original figures of *rubra*. Thus a gradation exists, in this respect; whether due to regional, to racial or to individual variation, forbidding the use of this feature as a specific character, unless much larger lappets should be found on some species of the genus, as yet undiscovered. In short, there seems no more warrant for separating *N. atlantica* from *N. rubra* on this ground, than on the size and exact conformation of the gonads.

A supposed difference between the two species, lies in the precise conformation of the pedalia, a character the diagnostic value of which can be tested only by the comparative study of more extensive and better preserved series. According to Broch (1913) *N. atlantica* is separated from *N. rubra* by (*inter alia*) tentacular pedalia longer, but less prominent, than the rhopalar, though the members of these two series are almost equally broad. But, so far as there is any information to the contrary, this may equally have been true of the original specimens of *N. rubra*, for Vanhöffen (1902, p. 30) informs us merely that "Ringfurche und Pedalien sind wohl ausgebildet," while his illustrations do not show the exumbrellar sculpture at all. Unfortunately no one of the Eastern Pacific specimens of *N. rubra* was in good enough condition to show the precise conformation of the pedalia, though the existence of these gelatinous prominences was obvious (Bigelow, 1909, P. 36). On the present example the ring furrow is well marked, and the pedalia in good enough condition to show that the members of the two series, tentacular and rhopalar, are approximately of equal size. Unfortunately the margin of the exumbrella is not in good enough condition to allow the distal outlines of the pedalia to be traced with certainty. As far as can now be seen, the tentacular and rhopalar series appear to be of about equal length, merging insensibly into the general contour of the marginal zone at their outer ends. But, in life they may have been more abruptly rounded.

When we remember how subject these gelatinous structures are to damage in the net, and the variability of the sculpture of the exumbrella in the related

genus *Atolla* (p. 505), it seems at least questionable whether the precise outline of the pedalia on preserved material can be given specific value here.

I have not been able to determine, definitely, whether the rhopalia of the *Arcturus* specimen were carinate. But re-examination of the rhopalium of an *Albatross* specimen of *N. rubra*, photographed in my earlier account (1909, Pl. 12, Fig. 6), proves that it is provided with an exumbral carina, such as Broch describes for *N. atlantica* and for *N. globifera*; Hartlaub (1907) for *N. limpida*.

This leaves, as a definite alternative character, between *rubra* and *atlantica*, only the presence or absence of exumbral nettle warts on the central disc. According to Vanhöffen, (1902, P. 30) the latter is "grubig punktiert" with such warts in *N. rubra* (his figures do not show this), while, in *N. atlantica* Broch (1913) describes the disc as smooth. Here, again, the Eastern Pacific specimens of *rubra* fail us by their fragmentary state. On the *Arcturus* specimen no warts are to be seen. And as the central disc is in good condition, it is safe to say that this was smooth in life.

The relationship of this specimen to *N. rubra* and to *N. atlantica* may, then, be summarized as follows:—with *N. rubra* it agrees closely in general conformation and in the shortness of the rhopalar lappets: with *atlantica* in the smoothness of the disc. It is intermediate, to some degree, between the two, in the size and conformation of the gonads. And it agrees with other members of the genus, and differs correspondingly from *N. atlantica*, in the conformation of the pedalia. In short, it forms a connecting link, thus making it probable that examination of larger series, in better condition and in various stages in growth, will prove *N. atlantica* to be, at most, a variant of *N. rubra*.

*N. rubra* (under this name) is already known from the Indian Ocean, from the Humboldt Current near the coast of Peru, near the Gallapagos, and between that group and Panama; likewise off the mouth of the Congo in the Tropical Atlantic. Its variant *N. atlantica* has been recorded from the Eastern Atlantic between the Azores and Europe. Thus *N. rubra*, like other bathypelagic Medusae, will probably prove world wide in the Tropical and Subtropical belt, if not in higher latitudes as well.

#### Family ATORELLIDAE.

##### Genus *Atorella*.

The collections made by the Valdivia Expedition contained an interesting new coronate medusa, with six tentacles and six rhopalia, instead of a multiple of four, which Vanhöffen (1902) christened *Atorella*. The one specimen (in poor condition), had only four gonads intact, a numerical nonconformity, between sex and marginal organs so unexpected, and entailing so irregular a radial relationship between them, that Vanhöffen thought it probable that the specimen had either lost two of its gonads, or was a sport. But the discovery of a second specimen, in the *Siboga* collection, by Maas (1903); and of 3, representing still another species of this *Atorella* type (A.

*vanhöffeni*) by the Albatross (Bigelow, 1909), proved this relationship between gonads, tentacles and rhopalia to be normal, and therefore a sound generic character.

The *Arcturus* collection now adds to the coronate series a form resembling *Atorella* in the number (6) of its tentacles and rhopalia, but differing from it in having six gonads instead of four, so that the gonads conform to the marginal organs in their radial symmetry, rather than to the stomach. Unfortunately (as is so often the case when oceanic medusae are first discovered), there is

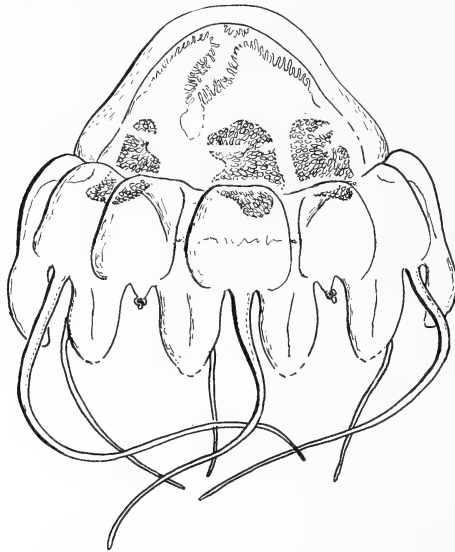


Fig. 180. *Atorella arcturi*, sp. nov.; side view of type specimen, 15 mm. in diameter.

only one specimen; and this one not in the best of condition. And radial reduplication, or suppression, is so common a variation among medusae (as in *Aurelia*) that this one specimen is best regarded as an aberrant *Atorella*. Specifically, however, it appears distinct from either of the members of the genus previously seen.

***Atorella arcturi*, sp. nov.**

Station 59, near Cocos I., Lat.  $3^{\circ} 52' N.$ , Long.  $86^{\circ} 43' W.$  600–0 fathoms. One specimen.

The specimen is in good enough condition to show the general form, and the more important anatomical characters. But most of the marginal lappets are broken off, and the subumbrella and manubrium damaged.

In general form (Fig. 180) this medusa is moderately domed, the central disc about 15 mm. in diameter, the marginal zone about 7-8 mm. broad, including the lappets. The exumbrel sculpture is of the usual coronate type, with well marked coronal and pedal furrows, the tentacular pedalia somewhat wider than the rhopalar. As far as can now be seen the central disc is smooth, with no trace of radial furrows; nor are any nettle warts to be seen. But as the specimen was evidently much rubbed in the net, these latter structures may have been lost. There is one marginal lappet between each tentacle and the neighboring rhopalium—a total of 12, just as in *Atorella*.<sup>3</sup> Such of the



Fig. 181. *Atorella arcturi*; suboral view of part of marginal zone, showing two gonads, tentacles and rhopalium.

lappets as are in good enough condition to indicate their normal outline are longer than broad, rounded at the tip and somewhat broader distally than at the base; longer and narrower than in *Atorella subglobosa* or in *A. vanhoeffeni*; but suggesting the lappets of the genus *Atolla*. The tentacles, all but one of which are still intact (the sixth is broken off near the base) are longer than the bell-diameter, tapering evenly to narrow tips, with no trace of the terminal knobs characteristic of *Atorella vanhoeffeni*. And as they are tolerably well preserved, this may be accepted as their natural state.

The tentacles, lying in the radii of the gonads, are, 2 interradial, 4 adradial with reference to the stomach.

The rhopalialia, alternating with the tentacles, and gonads, are 2 interradial and 4 perradial. Each rhopalium is situated at the tip of a small triangular

<sup>3</sup> Maas' (1903, Pl. 3, Fig. 6) illustration of *A. subglobosa* suggests twice as many. But this was evidently the result of mutilation, all the lappets being torn short off at the base; and such parts of the margin of the present specimen as have lost the lappets, give a similar picture.

lappet of the margin (Fig. 181) intermediate, in length, between those figured by Broch (1913) for *Nausithoe atlantica*, and illustrated here by the *Arcturus* specimen of *N. rubra*.

The sense organs, themselves, are of the usual coronate type. Unfortunately none of them are in good enough condition to show whether ocelli are present or not.

*Gonads.* The specimen is apparently a male, for surface views show the gonads crowded with sexual masses of various sizes and shapes; evidently not ova. As already noted, there are six gonads. All of these are fundamentally interradiial with reference to the symmetry of the stomach. But while two of the interradiial sectors have only one gonad each, each of the other two sectors includes a pair of gonads, so that these four are actually adradial in location.

The gonads, themselves, are irregular in outline. The four adradials are best described as roughly shield shaped, each of them incised, in outline, near the proximal end, on the side farthest from its fellow. One of the interradiial gonads is roughly pentagonal, the other oval, and much smaller than the rest. The gonads are separated by considerable spaces in the perradii: but the adradial ones are in such close proximity in the interradii, that only slight growth would be required, to bring the members of each of these 2 pairs into contact with each other. And conditions in the related genus *Nausithoe* make it likely that this does actually happen at full maturity, at least in some specimens, if not in all. Distally the gonads of the present specimen extend outward to the edge of the muscular zone, but this may not be their final limit in that direction.

The base of the four-sided stomach is asymmetrical, corresponding to the radiality of the gonads, the two sides which have pairs of gonads opposite them being considerably longer than the 2 other sides, each of which has only one gonad abreast of it.

The aboral (basal) part of the gastric cavity, with its taeniolae, and its relationship to the subumbrella, suggests the *Periphylla* type, rather than *Atorella vanhoeffeni*, or any of those members of the genus *Nausithoe* for which these structures have been fully described. Thus the base of the stomach is relatively voluminous, corresponding to the arched contour of the bell, and there are four deep, subumbral funnels (the so-called subgenital pits), penetrating, centripetally, nearly to the apex of the bell, between subumbrella and gastric wall. The corresponding ridges on the gastric floor, (the taeniolae) are triangular in outline (Fig. 180); and the cirri which they bear thus form a cruciform figure, leaving vacant, at the apex of the dome, an area occupying about  $\frac{1}{8}$  the diameter of stomach along its radius of curvature. The cirri are arranged in a single row of 10-12 along each edge of each of the taeniolae, with a cluster at the tip. In this, as in the form and extent of taeniolae and of subumbral funnels, *arcturi* (and apparently *Atorella subglobosa*, to judge from Maas' (1903, Pl. 3, Fig. 6) picture of the latter) resembles the more simply organized of the Periphyllidae, as represented by *Periphyllopsis* (Bigelow, 1909, Pl. 12, Fig. 1), more closely than the typical Nausithoidae; or than its close ally *Atorella vanhoeffeni*.

The distal portion of the gastric cavity (manubrium) is badly battered; such parts of it as still remain show that it extended at least to the level of the opening of the subumbrellar cup.

The condition of the specimen does not allow description of the distal canal system; except that (as usual, in this family) there is one broad radial pouch in the radius of each tentacle, and of each rhopalium. Presumably these are continuous, one with another, via a festoon canal, at the tips of the lappets. But I have not been able actually to trace this connection on the few lappets still present.

The ring-muscle is weak; the tentacular plates are not now apparent.

The preserved specimen is colorless, showing no trace of the deep reddish or brownish pigmentation which we have learned to associate with the bathypelagic habit, among scyphomedusae.

#### Family ATOLLIDAE.

#### Genus *Atolla*.

The history of the genus *Atolla* is typical, for the bathypelagic group of medusae, for as one deep sea expedition after another brought battered specimens to light, nine species, supposedly distinct, were proposed. But as greater numbers of specimens were studied, the number of these species was successively reduced, until it now seems likely, says Browne (1916), that all the *Atollas* which have yet been seen, represent variants, or contraction-phases, of two species only; *A. wyvillei* (the earliest named), with smooth lappets, and *A. chuni*, in which each of the lappets is studded with 7-9 small papillae.<sup>4</sup> Even the sculpturing of the central lens; whether with or without radial furrows at its margin, with the degree of development and exact confirmation of these when present, is found, by Browne (1916), to be less reliable as a systematic character than previously supposed. And this conclusion is supported by the present series, which shows intermediates between the *bairdii* type, with smooth central lens; the *verrillii* type in which the lens is scored with narrow radial furrows; and the *wyvillei* type where at least the edge of the lens is indented with broad radial notches, though its central portion may be smooth.

This character, then, goes into the same discard with most of the others which have been used to separate "species" of *Atolla*; relative breadth of the septal nodes for example, and the number of antimeres.

<sup>4</sup> For a survey of the successive advances in our knowledge of this genus, see especially Haeckel 1880, 1881; Vanhöffen 1902; Maas 1904; Bigelow, 1909, 1913; Mayer, 1910; Broch, 1913; Browne, 1916.



It was long ago observed (Fewkes 1886; Maas 1897) that some Atollas, when taken, or after preservation, show a smooth anular zone between ring furrow and tentacular pedalia, which is not visible on surface views of other specimens. This difference, according to Vanhöffen (1902) represents merely a contraction- or compression-phase, for none of the *Valdivia* specimens of *Atolla* lacked this zone intermediate between coronal furrow and pedalia, though in some it was concealed by the everhanging margin of the central lens. Mayer (1910) has, however proposed the presence or absence of this zone anew, as a specific character, dividing the Atollas with smooth lappets into *bairdii* with it: and *wyvillei* lacking it. This supposed difference has not been discussed by later writers, and therefore demands a word of comment here.

No special attention was payed to this character in my study of the *Albatross* Atollas from the Eastern Tropical and Northwestern Pacific, beyond the fact that in most of them this zone was concealed (Bigelow 1909, Pl. 9, Fig. 3, Pl. 10, Fig. 9). Reëxamination of some of these specimens gives the following results.—Out of 8 specimens, in fair condition, from off Japan ("Eastern Sea," Albatross Station 4907), 30–65 mm. in diameter, seven have the central lens overhanging, and nearly entirely concealing the anular zone, while in one specimen the central lens is much more elevated, leaving the edge of this zone visible, in aboral view.

Two out of three excellent specimens from Bering Sea, Albatross Station 4766, with disc very flat and firm, show no distinct intermediate zone, in aboral view, their pedalia seemingly separated from the margin of the central lens only by the coronal furrow. The third, in equally good state, shows an intermediate zone much narrower than the length of the tentacular pedalia.

As a radial section though the bell of this last specimen shows, the coronal furrow is very deep when this intermediate zone is nearly or quite concealed: deeper, in this case than the length of the tentacular pedalia. And the connecting zone below it, between central lens and peripheral zone, is narrow. Another much flattened specimen, also from Bering Sea (Albatross Station 4773), about 35 mm. in diameter, also has the central lens practically in contact with the pedalia. And among the Atollas which I have examined such has been the condition in general, in the specimens in which the gelatinous substance was firmest, the bells flattest, and the

pigment most nearly intact after preservation, i. e. in those that were probably alive when placed in the preservative, and so may be supposed to have suffered muscular contraction. This same state is shown by Vanhöffen (1902, p. 5, Fig. 24).

Two other specimens from this same station, respectively of 35 and 45 mm., with the central part of the disc more elevated, and the gelatinous substance softer, show intermediate zones between ring furrow and pedalia, nearly as wide as the latter.

The great majority of the large *Arciurus* specimens, listed below, illustrate a still more relaxed state, with the whole medusa softer and more cup shaped, the central lens bulging higher above the level of the ring furrow, the marginal zone hanging downward, and the smooth intermediate zone about as broad as the tentacular pedalia are long: in some cases even broader.

Radial sections of specimens of this type show the basal connecting zone at the bottom of the coronal furrow, between periphery (corona) and central disc, relatively thicker ( $\frac{1}{3}$ – $\frac{1}{2}$  as thick as the coronal furrow is deep) than is the case when the smooth annular zone is less prominent; furthermore, in such specimens the relaxed annular zone is much softer in texture than the pedal zone.

As has long been known, this connecting zone is the site of a circumferential strand of contractile fibres; and complex series of such fibres are imbedded in the gelatinous substance of *Atolla*.

In short, the apparent presence or absence of the smooth annular zone, has no genetic significance in *Atolla*. Every gradation is to be found (among specimens in different state of contraction or relaxation) from those in which no such band can be distinguished, other than the smooth outer wall of the coronal furrow, to others showing a protruberant band of this sort, as broad as the pedalia are long and which may or may not be marked off from the latter by a furrow.

Such differences do not indicate the existence of varieties, but reflect nothing more than the state of the animal—whether still alive, or dead and flaccid—when placed in the preservative, or the amount of muscular contraction it may have experienced, in the latter.

All of the *Atollas* in the present series (all have smooth lappets where these are intact) are therefore referred to the oldest named species, *A. wyvillei*. Notes on their condition, as regards the

annular zone, and the radial notching of the central disc, will be found below.

*Atolla wyvillei*, Hackel.

*Atolla wyvillei*, Haeckel, 1880, p. 488; 1881, p. 113, pl. 29, fig. 1-9.

Synonymy, see Mayer, 1910, p. 563, 565, 567 ("A. bairdii," + "A. valdiviae" + "A. gigantea" + "A. wyvillei").

Station 33, 700-0 fathoms; 2 specimens, in fair condition, one about 95 mm. in diameter, fully relaxed and with central lens showing only faint notching at the margin; the other, 38 mm. in diameter, flattened, and contracted, so that the intermediate zone is concealed in the coronal furrow, and with central lens deeply notched with narrow furrows at the margin.

Station 39, 250-0 fathoms; 2 specimens, about 10 and about 20 mm. in diameter, in poor condition.

Station 50, 1200-0 and 400-0 fathoms, 2 specimens about 21 and about 25 mm. in diameter, both fragmentary and relaxed, showing intermediate annular zone; one with smooth, the other with slightly notched central disc.

Station 59, 600-0 fathoms, 6 specimens, 20-35 mm. in diameter, all soft and fragmentary.

Station 68, 600-0 fathoms, 1 specimen, 90 mm. in diameter, relaxed; shallow indentations at margin of disc; annular zone as broad as pedalia are long, and demarked by narrow lines of pigment.

Station 74, 600-0 fathoms, 7 specimens, 17 to about 85 mm. in diameter; all soft, and more or less fragmentary. Most of these show a broad annular zone; but in the two best (40 and 35 mm.), the notched margin of the central disc conceals all but its outer edge, so that these specimens are precisely intermediate between the *Bairdii* and the *Wyvillei* types.

Trawl hauls from 625 and 749 fathoms also yielded 6 more, of 30 to 100 mm., somewhat damaged, and soft, of the *Bairdii* type, some with traces of furrows at the edge of the disc.

Station 84, 400-0 fathoms, fragments of one small specimen. 700-0 fathoms, 2 specimens of about 38 mm., much damaged; both of these show narrow annular zone, combined with narrow radial furrows at the edge of the central disc.

Station 86, 400-0 fathoms: four specimens, 80-100 mm., somewhat damaged, but all showing the annular zone. In two the central disc is perfectly smooth: in two it is slightly notched at the margin. 1000-0 fathoms, four specimens, 38 to about 76 mm. in diameter; all with broad annular zone showing; 3 with smooth disc; one with the disc showing traces of radial notches at its margin.

Station 100, 1098-0 meters, one 14 mm. in diameter, fragmentary. 2192-0 meters, fragments.

Station 105, 500-0 meters, one, about 20 mm. in diameter, fragmentary. 600-0 meters, one, of about 26 mm. with perfectly smooth disc, and poorly defined annular zone.

Station 108, 600-0 meters, one, about 43 mm. in diameter, in fair condition with broad notches at margin of disc only; and narrow but sharply defined annular zone.

Station 113, 500–0 meters, 2 specimens, 23 and 30 mm. One shows broad notches at the margin of the lens, and annular zone about as broad as the pedalia. The other has narrow radial furrows at the margin of the disc, and the annular ring is covered and concealed by the latter. These are intermediate between the *Bairdii* and *Wyvillei* types. 900–0 meters, one of about 20 mm. very fragmentary. 1200–0 meters; one, of about 85 mm. in good condition. The margin of the disc shows traces of radial indentations; the annular zone is very prominent and broader than the tentacular pedalia are long: *Bairdii* type.

Among 10 specimens taken at random, 3 had 21 tentacles; 3 had 22; and 4 had 24, with corresponding numbers of marginal sense organs. None of the specimens are in good enough condition to add anything to previous knowledge of the anatomy of this genus. Most of the captures (stations 33–86) are from the Equatorial Pacific, in the Galapagos-Cocos. I., region, where the expeditions of the *Albatross* 1891 and 1904–1905 had already proved *Atolla wyvillei* widespread (Maas, 1897; Bigelow, 1909, Pl. 48). The list also includes four Atlantic stations; one a few miles south of Bermuda (Sta. 100); one in the offing of Cape Hatteras (Sta. 105); one (108) just outside the continental slope, off Chesapeake Bay; and one at about the same relative position in the offing of New York.

*Atolla* has been taken at many stations in the Eastern North Atlantic, as well as along the continental slope in the offing of the coast sector, Cape Hatteras—Cape Cod. These *Arcturus* records are, however, of considerable faunistic interest, because the *Bache* failed to find a single *Atolla* in the oceanic triangle Chesapeake Bay—Bermuda—Bahamas during the winter of 1914, although numerous tows were made down to 1000 meters (Bigelow, 1918, P. 434).

With many summer records for that general region,<sup>5</sup> none for winter, a seasonal periodicity for *Atolla* in these comparatively high latitudes is suggested, with the maximum abundance in summer and early autumn. Until it is known whether *Atolla* is holoplanktonic, or whether, like many scyphomedusae, it passes through a fixed stage in its early life, such a periodicity is difficult to interpret. And in equatorial waters we have, as yet, no evidence of any such fluctuations in its abundance with the change of the seasons.

The *Arcturus* records are also instructive, bathymetrically. The shoalest Pacific capture was from about 500–0 meters. And so many shoaler tows were made during the expedition, that *Atolla* can hardly have occurred shoaler than about 500 meters in the Galapagos region at the time, unless accidentally. The shoalest Atlantic records, for the *Arcturus* series, are also 500–0 meters: and the same reasoning applies. When an *Atolla* is occasionally taken at the surface, this represents a sporadic excursion upward, out of its normal habitat.

#### Family LINUCHIDAE.

##### Genus *Linuche*.

These small, thimble-shaped medusae are among the most familiar of their tribe in West Indian waters and in the neighboring

<sup>5</sup> All Fewkes, and Broch's records are for the months of June–November.

parts of the Atlantic; equally widespread, too among the Malaysian archipelago. And they have repeatedly been described and pictured. Nevertheless, their wide variability, individual and swarm, makes it still an open question how many subdivisions of the genus deserve the rank of species.

At one time or another, nine such have been named, and four genera. But recent students have condensed these to two at the most, the interrelationships of which still remain puzzling. These are the small, brownish-tinted *L. unguiculata* (perhaps separable into two recognizable races), and a larger green form, for which Thiel (1927) has recently revived Haeckel's (1880) name *draco*, which had previously been relegated, by Mayer (1910), to the synonymy of *unguiculata*.

Mayer (1910) believed that, in the *unguiculata* group, a pacific form (*aquila*) could be distinguished from an Atlantic (*unguiculata*) by the arrangement of the subumbral pouches. And Stiasny (1924) has recently recorded *Linuche* from Malaysia as *L. unguiculata* var. *aquila*. Vanhöffen (1913), however, by his discovery of the supposedly Pacific variety as well as of the supposedly Atlantic, among *Linuche* from the Tortugas, Florida, proved that the two are not separated geographically. This Thiel (1927) substantiates by again finding Atlantic specimens (from Hayti) showing the arrangement of subumbral sacs which Mayer (1910) had thought typical of the Pacific *aquila*. This according to Thiel, indicates the co-existence in the Atlantic of two distinct forms of *Linuche* of the *unguiculata* group, either varieties (*aquila* and *unguiculata*) of one species, or possibly distinct species. But the great variability in the number and in the radial location of the subumbral sacs of the *Acturus* series, and of other specimens in the Museum of Comparative Zoology, described below, tends rather to support Vanhöffen's (1913) explanation of the difference between *unguiculata* and *aquila* as due, simply to individual variation. They are therefore united here, following him, under the older of the two names. I have had no opportunity to study the form recorded by Thiel (1927) as *L. draco*.

*Linuche unguiculata* (Schwartz).

*Medusa unguiculata*, Schwartz, 1788, p. 195, Taf. 6, Fig. 1.

Synonymy see Mayer, 1910, p. 558 ("*L. unguiculata*"), 560 ("*L. aquila*");

Vanhöffen, 1913, p. 429.

Station 69, near Cocos I., May 14, 1925. Depth?, 4 fragmentary specimens, all about 6 mm. high.

Station 96, southeast of Bermuda, July 11, 1925: surface. 43 specimens in fair condition, 6- about 10 mm. in diameter, with the gonads in various stages of development. All appear to be females.

Although the general organization of *Linuche unguiculata* is well known,<sup>6</sup> the present collection offers an opportunity to add some details as to the arrangement of the subumbbral sacs, the growth of the gonads, and as to the color patches (so conspicuous a feature of the subumbrella, in life), which are now known to be due to infestations of yellow or brown Algal cells, not to pigment produced by the Medusa itself (Thiel, 1927).

*The subumbbral sacs.* These curious pouch-like diverticula, hanging into the bell-cavity from the oral walls of the radial pouches, characterizing the family, are so conspicuous that they have figured in most of the published descriptions. But there has been some confusion as to their radial arrangement and number.

The most recent pictures of West Indian *Linuche* (Mayer, 1910, P. 59, Fig. 7, and P. 560, Fig. 356A) show three concentric rows of these sacs; an innermost (of 8) per radial and interrational with respect to the radially of the stomach: an intermediate row also perradial and interrational so that they alternate with the 8 arms of what are originally 8 separate adradial gonads; and an outermost row of 32, two of them to each radial pouch. On Pacific specimens, however, Mayer (1910, p. 560, Fig. 356b) found only 2 rows, the inner of 16, 4 of them perradial, 4 interrational, and 8 adradial, i. e. in the radii of the gonads and interrupting the latter midway of their length.

The *Arcturus* series, and also series in the collection of the Museum of Comparative Zoology, from Florida and from Fiji, are all essentially of the Pacific type so far as the radial arrangement of these pouches is concerned, though the number of concentric rows may be either two or three, while the relationship of the sacs to the gonads alters with the growth of the latter.

In young specimens with small gonads (exemplified by the *Arcturus* specimens from station 96, Fig. 182) the arrangement is as follows:—1) an outermost row of 32, two to each radial pocket, situated just centripetal to the band of circular muscle fibres; 2) an intermediate row of 16, consisting of one large sac at the tip of each gonad (adradial), 4 others perradial and 4 interrational; and 3) the innermost row, represented by 4 small interrational sacs close to the margin of the stomach.

Only one of the 4 Pacific specimens from Station 69 is in good enough condition to show the arrangement of the sacs. In this one the outer and intermediate rows are as just described (the adradial members of the latter in contact with the tips of the gonads). But the innermost row is represented only by a very small sac in one of the interrational.

This basic arrangement is shown (Fig. 182). All the specimens which I have examined show this same radial arrangement of the intermediate row, namely 4 perradial, 4 interrational and 8 adradial; but there is much variation with regard to the innermost row.

Among slightly larger Atlantic specimens collected by the *Bache*, for ex-

<sup>6</sup> See Mayer, 1910, for a good general account.

ample (Bigelow, 1918), one with gonads of medium size (Fig. 183) has perradials as well as interradians in all three of the rows of sacs, with adradials in the outermost and in the intermediate rows, making a total of 56. And this seems to be the maximum number ever attained. But others among this same series have only 2 rows in the perradii with 3 in the interradii, agreeing in this with the *Arcturus* series.

A collection of large adults from Palm Beach, Florida, from Dr. Thomas Barbour, increases the range of variation, for while one has the innermost row of sacs represented in the interradii (but not in the perradii), most of the specimens lack this row altogether. And another, with large gonads (Fig. 184), not only lacks the innermost row, but also the adradial members of the inter-

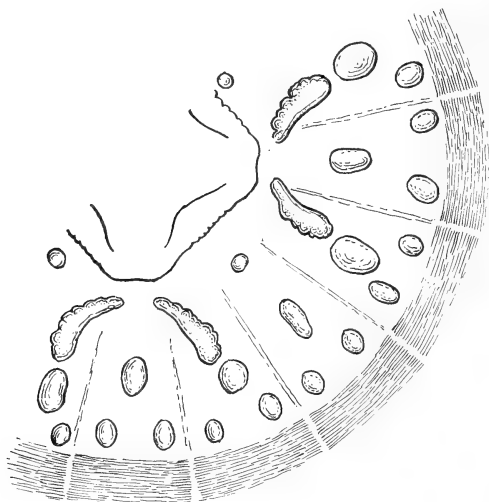


Fig. 182. *Linuche unguiculata*; portion of subumbrella, to show relative positions of gonads and of subumbral sacs in a specimen about 8 mm. in diameter, from *Arcturus* Sta. 96.

mediate row. The total of only 40 sacs, in this example, is the smallest number so far found in any adult specimen.

Thus the collections which I have examined corroborate Vanhöffen's (1913) conclusion that no distinction can be drawn between the Atlantic and the Pacific representatives of *Linuche*, with regard either to the number of concentric rows in which the subumbral sacs are arranged, or with regard to their number.

According to Maas (1903), in the Malaysian specimens collected by the Siboga Expedition, the sacs are differentiated from the rest of the subumbrella by a thickening of the ectoderm. This, however, seems to have been a misapprehension, based on surface views. Serial sections show that the pavement-

like ectoderm is no thicker in the sacs than elsewhere, but that it is underlain there by a layer, several cells thick, of the "yellow cells" (p. 514).

Haeckel (1880), misled perhaps by the superficial resemblance which these closely crowded yellow cells, in poorly preserved material, bear to the male sex cells of other medusae,<sup>7</sup> suggested that the sacs might be the male gonads. This, however, was disproved long ago (Maas, 1903.) But while the

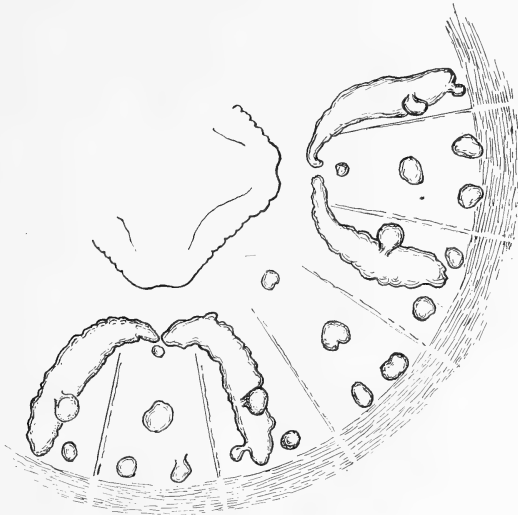


Fig. 183. *Linuche unguiculata*; portion of subumbrella of Atlantic specimen 11 mm. high, to show gonads and subumbral sacs (M. C. Z., No. 3076).

sacs may be assumed to have to do with digestion or, as Thiel (1927) suggests, with respiration, their true function still remains unknown.

*Gonads.* In young specimens, about 3-5 mm. in diameter, collected by the *Bache* between Florida and the Bahamas (Station 10203) in March, 1914 (Bigelow, 1918, P. 401) the gonads are already visible as 8 separate oval thickenings of the entoderm in the oral gastric wall, arranged in pairs, one in each of the adradial pouches, close to the margin of the stomach. This corresponds to the stage illustrated by Mayer (1910, P. 59, Fig. 5) for an *Ephyra* 4 mm. in diameter, and thought by Haeckel (1880) to characterize the genus *Linuche*. With growth the members of the pairs of gonads which flank each perradius become curved, their concavities toward each other, while still separate at their centripetal ends. And most of the *Arcturus* specimens are in this stage.

With continued growth (genus *Liniscus* of Haeckel) the centripetal ends of the members of each pair of gonads come together in the perradii, resulting

<sup>7</sup> "In einigen Fällen waren die Säckchen dicht gefüllt mit sehr. kleinen rundlichen Zellen, welche dieselbe Grösse wie die unreifen Sperma-Zellen anderer Medusen hatten." (Haeckel, 1880, p. 493.)



in four horse-shoe shaped figures, the arms of which extend outward along the adradial pouches. At the same time the gonads grow centrifugally, surrounding the adradial members of the intermediate circle of subumbbral sacs, and reaching outward until their outer ends closely approach, or touch the outermost circle of sacs. Most of the *Bache* specimens from Station 10203, (females) just mentioned, exhibit this stage, as did the Pacific *Linuche aquila* figured by Mayer (1910, P. 560, Fig. 356 C).

All of these, and such of the *Arcturus* series as have been sectioned, besides large adults from Fiji in the collection of the Museum of Comparative Zoology, are females, with large ova in various stages in development. And it is not known whether the gonads of this sex (easily recognizable as female at maturity by the folded and frilled appearance of the gonads as seen in surface view) grow larger than this: in fact this stage is farther advanced than most of the adults that have previously been figured. But ripe males from Palm Beach, Florida, collected by Dr. Thomas Barbour,<sup>8</sup> have still larger gonads (Fig. 184); these having grown out beyond the outer circle of subumbbral sacs, making the neighboring members of the latter seem like outgrowths from the margins of the gonad-arms. On some of these specimens the gonads reach just to the inner edge of the zone of circular muscle fibres, and at their inner ends are closely apposed in the perradii but show no signs of approaching each other in the interradii. On other examples the gonads reach out part way across the muscular zone (visible right through the muscle fibres, even in oral views of preserved specimens, both stained and unstained), while at their inner ends lobar outgrowths toward the interradii narrow the intervals between them. And in one example the gonads not only reach right across the muscular zone, to the bases of the marginal lappets, but their proximal ends have come into contact with one another in the interradii as well as in the perradii (Fig. 184), corresponding to Haeckel's (1880) genus *Linanthe*.

In the males of *Linuche*, unlike the females, the surfaces of the gonads are smooth, so that in the adult stage these organs superficially resemble those of certain Trachomedusae: *Halicreas* in particular.

*Colored Patches.* The presence of deeply colored spots or patches of brown, yellow or green, on the subumbrella of *Linuche*, has been mentioned by most of the authors who have written of the genus, though their true nature seems not to have been understood, until very recently. Thus Haeckel (1879, pl. 29, Fig. 6; 1880, p. 492) interpreted the opaque patches by which they are represented in alcoholic specimens, as areas of union between the exumbbral and subumbbral walls of the radial pouches. Fewkes (1882, p. 260), speaks simply of the subumbrella of *Linuche* as "thickly pigmented." And Mayer (1910, p. 559), speaks of the brown color as "numerous, separated, more or less polygonal areas of digestive cells in the gastric pouches."

Thiel (1927), however, has now shown that in reality these patches, both in *L. unguiculata* and in *L. draco*, reflect the presence of algal cells, corresponding to the so-called yellow cells or zoochlorellae of various other coelenterates. And this I can corroborate from microscopic sections of the present series. These "yellow cells" are oval or spherical in outline, about .006-.007 mm. in

<sup>8</sup> Curiously enough, surface examination has revealed no females among this series.

diameter, with definite cell wall, granular contents, deeply staining nucleus, and usually with one pale-staining area. Among them, various stages in division are to be seen. Thus they very closely resemble, both morphologically and in their mode of reproduction, the corresponding structures in *Cassiopea*, the vegetable nature of which was demonstrated by R. P. Bigelow (1900).

To find these algal cells in *Linuche* is, of course, in no way remarkable: witness their well known presence in many Rhizostome medusae, as well as in Actinians, Hydrocorallids, Alcyonarians, etc. So far as I am aware, however, they have not been reported in any others of the Coronatae, or among Saemostome medusae.

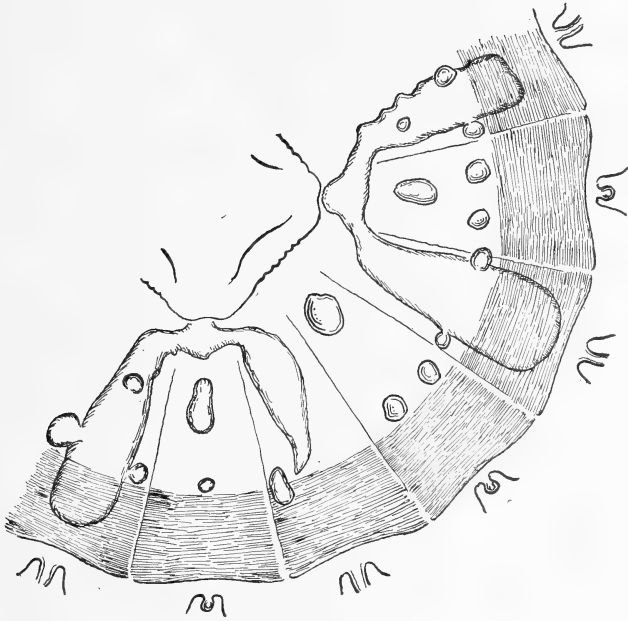


Fig. 184. *Linuche unguiculata*; portion of subumbrella of Florida specimen about 12 mm. in diameter, with very large gonads.

In the *Arcturus* specimens, the colored patches (119 in one specimen) are scattered around the periphery of the subumbrella, distal to the outer circle of subumbrellar sacs, 2-5 in number per radial pouch, and extending out into the marginal lappets, each of which also has 2-5 patches. Usually the patches are roughly oval, or sausage shaped, often two in contact: and individual patches may be bifid. The yellow cells are situated in the oral wall of the radial pouches, next to the muscular layer, or to the mesogloea, in a layer several cells deep, as described by Thiel (1927). The endodermal epithelium between these patches

in this zone, is composed of a single layer of flat pavement-like cells. And although the histologic fixation (in formalin) is not of the best, fragments of the endothelium can be discerned here and there, enclosing the "yellow cells": evidence that the latter multiply between the entoderm and the mesogloea, or muscular layer as the case may be.

In the specimens examined from Station 96 no yellow cells were to be seen in the interspaces between the patches, or in the subumbral wall between the latter and the gastric sacs. But they infest the entoderm of the latter, in a layer several cells deep: it was here in fact, that Thiel (1927) recorded them, and that Haeckel (1880, p. 493) had long ago seen them, though without realizing their true nature (p. 513). In several cases masses of the yellow cells were found intruding from a subumbral sac into the lumen of the neighboring part of the radial pouch, but this may be the result of the poor fixation of the material.

One, at least, of the Pacific specimens from Station 69,<sup>9</sup> shows a more extensive infestation, with the patches of yellow cells in the outer part of each radial pouch confluent, so that the whole oral surface from the muscular zone out to the tips of the lappets, is involved, except for very narrow pale lines, mirroring the demarkation between the discrete yellow patches of an earlier stage in development. In this specimen, too, the inner (centripetal) parts of the pouches are also infested, each with one or two large, angular patches, separated from the distal infestation by only a narrow band, just distal to the outer circle of subumbral sacs.

In slightly larger specimens from Fiji (also females) cross-sections and surface views show the yellow cells spread over the whole subumbral surfaces of the radial pouches, from their proximal ends, outward to the edges of the lappets, including the subumbral sacs. In the region of the muscle zone, a polygonal subdivision of the infestation by narrow lines, suggests that at a younger stage, the yellow cells had been in separate patches. And these subdivisions appear as pale bands in Mayer's (1910, pl. 59, Fig. 11) painting from life of one of this same Fijian series.

In the localization of the yellow cells in the entoderm, perhaps also extending into the lumina of the radial pouches, *Linuche* agrees with *Cotylorhiza* among the rhizostomes (Mayer, 1910) and differs correspondingly from *Cassiopea*, in which they are most plentiful in the mesogloea of the umbrella, though occurring to some extent in the entoderm also (R. P. Bigelow, 1900).<sup>10</sup>

*Color.* The *Arcturus* specimens (in formalin) now show a pale brownish tinge: no notes as to their color in life are available.

*Geographical distribution.* The range of *Linuche unguiculata* is restricted to tropical and subtropical waters, but includes all three great oceans; chiefly, however, near land. In the Atlantic it is widespread and abundant in the Floridan-West Indian-Bahaman-Caribbean region generally, and in the Gulf

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<sup>9</sup> The others are not in good enough condition to show the limits of distribution of the yellow cells.

<sup>10</sup> For a further discussion and illustrations of the yellow cells of *Linuche*, see Thiel, 1927.

of Mexico. The Bermudas seem also to be a center of production for it; witness the *Bache* record about fifty miles to the northwest of that group; (Bigelow 1917, chart, Station 10176); likewise the *Arcturus* captures 270 odd miles to the southeast (Station 69). In the eastern side of the Atlantic *Linuche* has been taken at the Cape Verdes, and thence southward, at various localities, along the west coast of Africa, to Angola.

In the Pacific it is known from the Gallapagos—Cocos Islands region in the east; from many localities in the South Seas; from Australia; from the Malaysian region; and from the neighborhood of Madagascar in the Indian Ocean.

On the whole it may be described as neritic in habit, suggesting that it passes through a fixed stage in its development. But there is a gap in our knowledge of its life history between the Planula stage (described by Conklin, 1908), and the young medusa.

## Order DISCOPHORA.

### Family PELAGIDAE.

#### Genus *Pelagia*.

*Pelagia* offers the interesting case of a genus, distinguishable from its relatives by precise and easily definable characters, but including a whole series of forms, the precise significance of which it has not yet been possible to determine. Certainly these forms, varieties or races, are not species in the sense in which this term is usually defined: not only are the extremes connected by unbroken series of intermediates, but they can not be correlated with geographic distribution. We have here, as Mayer (1910, p. 571) remarks, one of those instances—not uncommon among medusae—where the Linnean System of classification is inadequate to express the relationship of the numerous closely related forms. If we are to use this system, it is reasonable to demand that species shall be recognizable; i. e. that the characters chosen to characterize them shall be such that at least the great majority of specimens can be referred definitely to one species, or to another: or, if the status of any considerable number of specimens be plotted graphically, the resultant figure must partake of the nature of a dumb-bell, not of an ellipse, before we can speak of distinct species; even of subspecies. If the intermediates prove to greatly outnumber the so-called "species," the classification breaks down. And this is just what has happened, in *Pelagia*, as one system after another has been subject to critical examination.

A brief statement of the several characters which have been so

tested will make this clear. The earlier students of the group devoted attention chiefly to the proportionate dimensions of bell, manubrium and mouth arms; to the outlines of the marginal lappets; and to the number, conformation and arrangement of the exumbrel nettle warts. And at least 18 supposed species or varieties (and perhaps more) have been founded on these characters, separately or in various combination.

Large series of measurements, by Vanhöffen (1902); Broch (1913); Kramp (1924) and Bigelow (1913), have, proven, however, that there is no discontinuity between specimens (or varieties) with relatively long, and those with relatively short, mouth arms, or manubrium. These proportions as Broch (1913) demonstrated, alter with age; the manubrium being shorter, relative to the mouth arms, in large medusae than in small. Similarly Kramp (1924) found no consistent difference in relative length of the mouth tube between Mediterranean and Atlantic Pelagias, except that it may average slightly longer in the former, which is directly contrary to earlier accounts. Neither did proportionate measurements, of themselves, give warrant for distinguishing more than one species among all the specimens from the Atlantic, Indian and Pacific Oceans, gathered by the *Valdivia* and by the *Albatross*.<sup>11</sup>

The *Albatross* and *Arcturus* specimens substantiate Vanhöffen's (1902) observation, latter corroborated by Broch (1913), and by Kramp (1924), that the precise conformation of the exumbrel warts has no greater diagnostic value. Browne (1916, p. 204), it is true, following Mayer (1910), believes that these warts "will yet prove useful for distinguishing races, if not species." But the *Valdivia* collection showed intermediates between the elongate warts of *noctiluca* and the rounded of *panopyra* (Vanhöffen, 1902). Broch (1913) found, among the large Atlantic specimens collected by the *Michael Sars*, all the different varieties of these warts, which have been used as specific characters. Kramp (1924) also found the warts highly variable in size, and shape; with no discontinuity between Mediterranean and Atlantic specimens, and with a tendency for large specimens to show more elongate, and larger warts than small; often with several coalescing in a row, which the specimens I have myself examined, corroborate. As I have previously remarked (1913, p. 89), large specimens invariably (in my experience)

<sup>11</sup> See Vanhöffen, 1902, Bigelow, 1909, 1913.

bear warts of various forms, ranging from round to oval, often linear; of various sizes; they may be more or less prominent; and either subdivided by transverse furrows, or smooth surfaced. In small specimens the warts usually—perhaps invariably—take the form of rounded knobs, and they are proportionably higher in small medusae than in large ones. Furthermore, Kramp (1924) has pointed out that the warts alter in shape, with contraction. It is likely, too, that they also alter, if any of the nematocysts be discharged under normal conditions. And they are more or less prominent according to the state of nourishment of the medusa.

The precise outlines of the marginal lappets has also been found so variable as to be worthless for specific characterization; in fact Kramp (1924) found lappets of different shapes on a given individual.

The only reasonable conclusion, from the evidence summarized above, is that one species of *Pelagia*, at any rate, occurs, widespread, over the warmer parts of the Indian and Pacific and Atlantic oceans, as well as in the Mediterranean. This, in fact, is just what was to be expected from analogy with other holoplanktonic medusae. To this species the oldest name—that of the Mediterranean form (*P. noctiluca*) must be applied.

It seems impossible—in the present state of our knowledge—to separate any of the other named species of the genus from this combined oceanic form; *noctiluca*. Even the three *Pelagias* recently described as new by Stiasny (1914, 1922), *P. purpurviolacea*, *P. rosacea*, and *P. curaçoensis*, all fall well within the range of variability of *noctiluca* as represented by the series collected on the high seas by the various deep sea expeditions. In fact, Stiasny (1924a, p. 84), himself states (corroborating earlier students) that the relative length of manubrium and mouth arms is unreliable, and that the nettle warts are not only of different shapes on different parts of the bell of a different individual, but change with age.

*Pelagia noctiluca*, Forskål.

*Medusa noctiluca*, Forskål, 1775, p. 109.

Station 26, Surface, 20 specimens, 7–70 mm. in diameter: 100–0 fath., 5 specimens 33–40 mm. in diameter.

Station 31, 500–0 meters, 22 species, fragmentary, 30–50 mm. in diameter.  
Station 57, Surface, several specimens, 4–7 mm. in diameter.

Station 59, 300–0 fathoms, fragments. 500–0 fathoms, about 75 juveniles, 3–5 mm. in diameter.

Station 74, Surface, 2 specimens, 14 and 16 mm. in diameter. Closing net, 500–300 meters, one specimen, 23 mm. in diameter.

Station 98, 300-0 meters, 1 specimen, 8 mm., in diameter.

Station 100, Surface. 5 specimens, 4 of them 5-10 mm., one 60 mm. in diameter. Also between Stations 96 and 97, southwest of Bermuda, surface, 4 specimens, 50-70 mm. in diameter.

From the systematic standpoint the *Arcturus* collection is interesting chiefly as cumulative evidence to the effect that no specific distinctions can justly be based on the shape of the exumbrel nettle warts, which show all possible gradations from round and dome shaped, to linear and ridge like. In all our small ones, they are of the former type. On a medium sized specimen most of the warts are round to narrow-oval (*perla* and *panopyra* types). Among the 4 large specimens of 50-70 mm. from the Atlantic, rounded to oval warts dominate in one; high, narrow and ridge like warts characterize the other three. And of these last, one has the marginal zone smooth (*cyanella* type), while in the other the margin, as well as the centre of the disc is warty (*noctiluca* type).

Most of the specimens have suffered so much in the preservation, that measurements of mouth arms and manubrium would be of little value. Certainly most of them fall well within the limits given by previous students.

The chief interest of the series is its demonstration that *Pelagia*, usually regarded as a surface medusa, may sink to a considerable depth: witness the capture of one in a closing net at least as deep as 300 meters (station 74). And this, it seems, is the greatest depth at which the presence of *Pelagia* is definitely established. It is also probable that the specimens from station 59 came from a considerable depth, because surface tows yielded none there. The captures are from the Gallapagos-Panama region, and in the Atlantic from the general vicinity of Bermuda, regions where *Pelagia* has already been recorded.

#### Family CYANEIDAE.

#### Genus *Cyanea* Linné.

*Cyanea capillata*, var. *fulva* L. Agassiz.

*Medusa capillata*, Linné, 1758, p. 660: *Cyanea fulva*, L. Agassiz, 1862, p. 119, 162.

Synonymy, Mayer, 1910, p. 596, 600.

One specimen, about 140 mm. in diameter, labelled "surface in the Gulf Stream July 25, 1925," which locates the capture in the offing of New York some 10 miles outside the continental edge as outlined by the 100 fathom contour.

This specimen is referable to the small yellowish variety (*fulva*), of the species, representative of the genus *Cyanea* along the middle Atlantic States, by its color (pale yellowish brown in formalin), and by the fact that the gonads are well developed at so small a size.

Stiasny's (1919-1922) recent studies of Atlantic and Indo-Pacific Cyaneas have brought out fresh evidence of the extraordinary tendency which this Scyphomedusa shows, to break up into environmental races, over its broad range. Whether any of these more or less recognizable forms deserve to be dignified with the name of species, as distinguished from the oldest known, *C. capillata*, of the North Atlantic and North Pacific, is still an open question. On the basis of such information as is yet available, it still seems wisest to class

all of them as varieties of *C. capillata* (Bigelow, 1913), for they are connected by intermediates, not only with respect to color, but also with respect to the several anatomical characters (marginal outlines of the lappets; number of tentacles: stage of development of gonads at different sizes), by which the extreme forms are separable.

At any rate it seems certain that all the Cyaneas that have yet been described from the east coast of North America must be so regarded, a very large, and deeply colored variety (*arctica*) prevailing to the northward of Cape Cod, giving place to smaller and paler Cyaneas off the middle (var. *fulva*) and south Atlantic United States (var. *versicolor*).<sup>12</sup>

Stiasny (1921) has recently demonstrated, by injection, that the tentacular and rhopolar radial pouches of his new varieties *Mjobergi*, and *Buitendijki* from Australia are connected in the muscular zone by many cross anastomoses, instead of being separated by continuous septa, as was formerly thought characteristic of the genus. And he suggests that, by proper methods of examination, this may perhaps be found the case in some of the northern varieties, as well. Unfortunately the rather fragmentary state of the *Arcturus* specimen has made it impossible to test this by injection. But surface views of dissections of the marginal zone so strongly recall Stiasny's (1921) figures of this anastomosis, and in just the same region (i. e. in the zone of the circular muscles), that its occurrence in the Atlantic var. *fulva* seems altogether probable, if not definitely proven.

There is nothing remarkable in the capture of an odd example of this neritic medusa over the continental slope in the warm saline water of the so called Gulf Stream at this latitude, for this variety of it is known from southern New England to the Carolinas. In July, 1913, for example, the *Grampus* had it at four stations in the coastal sector between New York and Chesapeake Bay (Bigelow, 1915, P. 317); at five stations between the offings of Delaware and Chesapeake Bays in August 1916 (Bigelow, 1922, P. 159).

Offshore records of this genus are always interesting, Cyanea, strictly of shoal-water origin, being one of the best of natural drift buoys to show expansions of coastal water. In the present instance, however, we lack the record of temperature and of salinity which would have shown whether the specimen was drifting southward, just inshore of the zone of contact between banks and oceanic waters, by the track followed by many drift bottles (Bigelow, 1927, P. 882), or whether it had actually crossed this zone, and had been picked up by the Gulf Stream drift toward the northeast. Judging from general knowledge of ocean dynamics along the North American seaboard, the first of these alternatives seems the more probable.

<sup>12</sup> For description of these, see Mayer, 1910.



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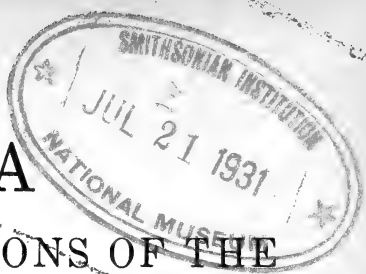
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SIPHONOPHORAE  
FROM THE ARCTURUS OCEANOGRAPHIC EXPEDITION

BY HENRY B. BIGELOW

*Museum Comparative Zoology  
Harvard University*

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# SIPHONOPHORAE

## FROM THE ARCTURUS OCEANOGRAPHIC EXPEDITION.

BY HENRY B. BIGELOW.

*Museum of Comparative Zoology*

*Harvard University.*

(Figs. 185-220 incl.).

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Moser (1925), in her general discussion of the classification of the Calyophorae, employs Claus' (1873) name Monophyidae for this family rather than Huxley's (1859) older name Sphaeronectidae, because Claus had appreciated, and stated in his definition of the family (based on his genus *Sphaeronectes*) which Huxley did not in writing of his *Sphaeronectes*, that the forms included develop only one definitive nectophore, i. e. that they are monophyid as a group. But the supposed differences between *Sphaeronectes* and *Monophyes*, in the form of the bell, in the precise situation where the subumbrellal canals originate, in the courses of the latter over the subumbrella, and in the outlines of the somatocyst seem to me, as they did to Schneider (1898), too slight to be regarded as anything more than specific.<sup>1</sup> These differences are in fact comparable to those that separate, one from another, the various species *Diphyes*, of *Diphyopsis*, of *Praya*, etc. With the relegation of *Monophyes* to the synonymy of *Sphaeronectes*, the International rules of nomenclature forbid the use of the name "Monophyidae" and demand the substitution of the older designation "Sphaeronectidae" as Schneider (1898) pointed out.

The question which Siphonophores rightly fall in this family of primitive forms will no doubt continue a perplexing one for some time to come, because of the uncertainty whether forms with only one nectophore, but highly organized in other respects, are in fact primitive or whether they are retrogressive, i. e. have lost the second bell. For such presumed degenerate forms Moser (1925, p. 387) has established a new family, Dimophyidae, as a sort of catch-all for offshoots from the Diphyids, from the Prayids, and from the Abylids. But if the classification adopted is to make any pretense at following phylogenetic relationships, such a union of offshoots from three different families is irrational, because to group them together obscures the very wide divergence, in evolution, of which they are

<sup>1</sup> For recent discussions of the status of the various named "species" of *Sphaeronectes* and of *Monophyes* see Bigelow, 1911 a, Moser 1925.



supposed to be the end products. If these reversionary groups are to be set apart from their parent stocks, each should logically be made a distinct family. That is to say, Moser's subfamilies Dimophiinae, Amphicaryoninae, Mitrophyinae and Cuboidinae should be raised to family rank.

The present collection contains examples of two genera of Monophyids, *Nectopyramis* and *Cuboides*. The latter Moser considers retrogressive (her Cuboidinae). But no direct evidence has yet been brought forward that *Cuboides* is in fact descended from ancestors with two developed bells. Moser's (1925, p. 81) two reasons for so interpreting it are its "ungewöhnlich hohen organisation," and the reduction of the stem to a small disc. But the first of these characters may (unless the contrary be established) be as reasonably regarded as evidence of progressive evolution from a primitive stock as retrogressive from a more specialized, while the second—reduction of the stem—may be independent of the ancestral number of bells. *Cuboides* is therefore included here, as in my earlier papers, under the Sphaeronectidae, where it falls on morphological grounds.

*Nectopyramis diomedae* Bigelow.

*Nectopyramis diomedae* Bigelow, 1911 a, p. 191, pl. 1, figs. 1-6; 1912, p. 65; Moser, 1925, p. 116.

Station 59, off Cocos Island, 1090-0 meters, one colony, much distorted and contracted.

One could wish that this specimen were in better condition, for so few examples of the polygastric generation of this species have yet been seen (total of 3) that every additional one is welcome. Fortunately the gelatinous substance of the bell of this *Arcturus* specimen, with its canals, is well enough preserved to make its specific identity certain, though the branching of the somatic canals is somewhat more complex than it was in the type specimen. Thus the canal which runs to the dorso-basal angle of the nectophore has five short transverse branches, contrasted with only two in the type specimen (Bigelow, 1911 a, pl. 1, fig. 1); the ventro-apical trunk has five very short side branches, whereas in the type it was unbranched. The dorso-apical trunk has one additional branch, and the canal that extends from the ventral subumbral canal to the ventro-basal angle of the nectophore has three small cross-branches instead of only one. But the two canals that ramify over the left and right faces of the hydroecium agree essentially with those of the type.

These slight differences are of a sort that may reasonably be credited to a slightly more advanced stage in growth.

Unfortunately the specimen is much distorted. However, it shows that the relative locations of hydroecium and nectosac are as in the original specimen, and that the conformation of the nectophore (39 mm. long) was essentially the

same. The subumbrella surface of the nectosac being destroyed, nothing can be said as to the subumbral canals, nor does any trace of the stem remain.

Previous captures of this species have been off the coast of Peru to the southwest of the Galapagos, and midway between that group and the Paumotos. The locality of capture of the *Arcturus* example corroborates this evidence of its wide occurrence in the Eastern Tropical Pacific. It has not yet been found in the Atlantic, though a closely allied species (*N. thetis*) has been described from the Bay of Biscay (Bigelow 1911).

*Cuboides vitreus* Quoy & Gaimard.

*Cuboides vitreus* [Eudoxid]; Quoy & Gaimard, 1827, p. 19, pl. 2 e, figs. 1-3. For synonymy see Bigelow, 1911 a, p. 190; Moser, 1925, p. 404; Browne, 1926, p. 60.

Station 74, 636-0 meters, complete Eudoxid, 2 loose bracts and one loose gonophore.

These specimens add nothing to the excellent description and figures that Chun (1892, pl. 11, 12) has given of the Polygastric generation (as "*Halopyramis adamantina*") and of the Eudoxids set free therefrom (as "*Cuboides adamantina*").

*C. vitreus* had already been found widespread in the Galapagos-Panama region, and off the coast of Peru by the *Albatross* in 1904-1905. Hence it was somewhat surprising that it was found at only one of the *Arcturus* stations, i. e. near Cocos Island.<sup>2</sup>

#### Family PRAYIDAE K  lliker, 1853.

This family, as here limited, includes two subfamilies, Prayinae and Amphicaryoninae. Moser (1925) has transferred the latter to her new family Dimophyidae. But as pointed out above, this grouping together of genera the phylogenetic relationships of which are believed to be diverse seems to me unnatural. And since it seems certain that *Amphicaryon* is closely allied to the more typical Prayids, from which it differs chiefly in the fact that one of its bells is degenerate, Chun's (1888) and my location of it as a subfamily of the Prayidae seems the more natural arrangement. Browne (1926, p. 60) also refers it to this family.

Both subfamilies are represented in the collection, Amphicaryoninae by *Amphicaryon* (its only known representative), Prayinae by its type-genus, *Praya*.

The history of the latter is a striking illustration of the nomenclatural difficulties that face the student of Siphonophores. The genus was founded by Blainville, in 1834, for a species, *P. dubia*, described and pictured almost simultaneously by Quoy & Gaimard (1834) as *Diphyes dubia*. And as Blainville's illustration was based on their specimen, there is, in this case, no doubt of the identification.

<sup>2</sup> For the locations and depth data of the *Arcturus* stations see Beebe (1926).

It was many years, however, before any Siphonophore agreeing with Quoy & Gaimard's excellent illustrations of *dubia* was again seen. Meanwhile the name *Praya* came into general use for another species (or group of species) closely allied to *dubia* but differing from it in the canalization of the nectophore. And when, after a lapse of more than three quarters of a century, the *Albatross* collected specimens of Quoy & Gaimard's old species, this difference proved so sharp as to demand generic separation. In my account the *Albatross* series (1911 a.) I therefore proposed the new genus *Nectodroma* for *dubia* Quoy & Gaimard and for a new species, *reticulata*. The former was also represented in the *Gauss* collection; and Moser (1925) agrees that it is generically distinct from the species that have usually been named *Praya*. But she points out (what I had overlooked) that, to accord with the nomenclatural principle of priority, that generic name must be given to *dubia*, because this was the only species referred to *Praya* by Blainville (1834) in his original description of the genus. This would entail the substitution of some other name for the form (or forms) that have commonly passed as *Praya*, and because of the confusion that might result, Moser considered a departure from the rules justified in this instance. But the case is so clear, *Praya* having been originally described as a monotypic genus for Quoy & Gaimard's *Diphyes dubia*, and there being no doubt as to the identity with the latter of the specimens of *dubia* recently taken, that the cause of eventual stability will better be served by adherence to priority. This entails acceptance of *dubia* as the type of *Praya*; and this course is followed here. Selection of a name for the Prayids that differ sufficiently from the latter in canalization for generic separation (typified by *Physalia cymbiformis* of Delle Chiaje, which has usually been known as *Praya cymbiformis*) may be left to the student who next has opportunity to study representatives of that group.

*Amphicaryon acaule* Chun.

*Amphicaryon acaule* Chun, 1888, p. 1162; Bigelow 1911 a, pl. 4, figs. 1-8;

Moser 1925, p. 399.

*Diplodoxia acaulis* (Eudoxid) Chun 1888, p. 1163.

Station 51, 500-0 meters, one specimen.

Station 105, 1274-0 meters, one specimen.

The condition of these two specimens is so poor that they add nothing to our knowledge of the morphology of this interesting Siphonophore. In one of them (Station 105) the larger nectophore is about 7 mm. high. The other specimen is larger (10 mm. in diameter) but so crushed in its polar axis that

its height cannot be estimated. It is interesting that the 7 mm. specimen shows much the same mutual relationship between the two bells (the small being flat, scale-like, and not at all enclosed by the larger) that characterized a 3 mm. specimen in the *Albatross* collection (Bigelow 1911 a, *pl. 4, fig. 8*). In the larger *Arcturus* example the larger bell encloses most of the smaller, the nectosac of which is well preserved.

Neither specimen adds to our knowledge of the appendages:—the stem of the smaller has been entirely lost; in the larger, only the bases of a few siphons (4, perhaps more) are still to be seen.

The three authors who have actually examined specimens of *Amphicaryon* of late (Bigelow 1911 a, Moser 1925, Browne 1926) differ as to whether its small degenerate bell is the upper (older) or primary one of the pair, or the lower (younger). Evidence for the first view, held by me and by Browne, is that in very young specimens this small bell is relatively much larger than it is in adults, and that it at first overlaps the nectophore that later comes to surround it. Moser who has confirmed these observations on material collected by the *Gauss*, reaches the opposite conclusion, chiefly on the theoretic ground that the degenerate bell is “von Anfang an functionsfähig und verkümmert” (Moser 1925, *p. 400*). This question must wait its positive answer, one way or the other, until some student has the opportunity to follow the development of *Amphicaryon* from a stage so young that it will be possible to trace the history of the two definitive bells from their earliest formation, and so to learn whether it is the first formed or the second that later degenerates.

As this Siphonophore has already been found in West Indian waters, among the Canaries, and at five *Gauss* stations in the Atlantic between L. 20° N. and 32° S., likewise widespread in the Eastern Tropical Pacific, there is nothing surprising in its representation in the *Arcturus* series. The considerable depth of these hauls, like those of the *Gauss* and *Albatross* that yielded it, indicate that *Amphicaryon* is more often bathypelagic than epiplanktonic.

*Praya dubia* Quoy & Gaimard.

*Diphyes dubia*, Quoy & Gaimard, 1834, *p. 104, pl. 5, figs. 34–36*.

*Nectrodroma dubia*, Bigelow, 1911 a, *p. 204*; Moser, 1925, *p. 381*.

Station 54, surface, 2 loose nectophores.

Station 74, 909–0 meters; 1 very fragmentary nectophore.

The nectophores from Station 54 apparently belong to a single colony, the one being somewhat larger than the other. But unfortunately the length cannot be stated for either, because the gelatinous extension below the level of the ventral face of the opening of the nectosac has been destroyed. The length of the larger bell from this point to apex is now 52 mm. that of the smaller 43 mm. The type of canalization of this Prayid, combining a large number of dichotomously branched radial canals on the nectosac, with branched somatic canals, is so characteristic that there is no danger of confusing its bells with those of any other siphonophore yet described. The *Arcturus* examples correspond so closely in this respect to those collected by the *Albatross* (Bigelow 1911 a, *pl. 3, figs. 8, 9*), by the *Gauss* (Moser 1925, *p. 382*), and a century ago by Quoy & Gaimard (1834) that only the minor points of difference need be noted.

In the larger of the two bells the pedicular canal divides into six subumbrals on joining the nectosac; these again subdivide dichotomously but irregularly until about fifty reach the margin of the bell.<sup>3</sup> The branching of the pedicular canal could not be traced in the *Albatross* specimens because of their condition, but there were at least fifty-five canals at the margin of the bell. Moser makes no statement as to this point, for the *Gauss* specimens, nor did Quoy & Gaimard.

In both the *Arcturus* bells the ascending trunk of the somatic system is unbranched, just as it was in the *Albatross* specimens. Quoy & Gaimard's examples, and the *Gauss* specimen show a more advanced stage of development with this trunk giving off several short transverse branches. The two main descending trunks into which the primary somatic trunk divides near the apex of the bell correspond, in the simplicity of their branching, to the *Albatross* material.

Moser (1925) and I have already argued that the presence of deep hydroecial furrows indicates a biserial rather than a coronal arrangement of the bells. The *Arcturus* capture of two nectophores, taken in the same haul though no longer connected, tends to support this conclusion.

Previous records for *Praya dubia* have been from the eastern side of the Pacific and from Australian waters. The *Arcturus* specimens are from the same general region as those taken by the *Albatross*, between the Galapagos and the American coast. The presence of this species off Valparaiso (Moser) and off South Australia (Quoy & Gaimard) shows that it is not confined to high temperatures.

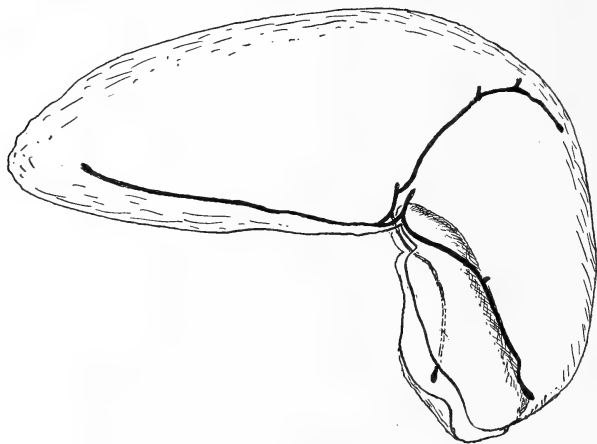


Fig. 185. *Praya reticulata*; bract,  $\times 3$ ; from offing of Monterey Bay, California.

*Praya reticulata* Bigelow.

*Nectodroma reticulata*, Bigelow, 1911 a, p. 206, pl. 1, figs. 7-8, pl. 3, figs. 1-7;  
Moser, 1925, p. 383.

<sup>3</sup> The margin is damaged so that the precise number of canals cannot be determined within one or two.

Station 26, 600-0 meters, two nectophores.

Station 39, surface, two nectophores.

Station 87, 1090-0 meters, one nectophore.

These bells are fragmentary, but show enough of the characteristic somatic-canal system to locate them in this species, rather than in *dubia*. In every case the subumbrella has been entirely destroyed, consequently they add nothing to previous knowledge as to the subumbral canals, the netlike arrangement of which is the most characteristic feature of this species.

As no account of the stem-groups has yet appeared, it will be appropriate here to describe detached stems taken off Monterey, California, in July 1928 (Bigelow and Leslie 1930) which are referable to these species because their bracts agree in all essential respects with those that were taken side by side with the nectophores of *P. reticulata* by the *Albatross* (Bigelow 1911 a, 1913).

The most characteristic feature of the bract is a curious asymmetry of the canal system, with the right hydroecial trunk giving off a long branch that runs directly dorsad, to the margin of the bract (Fig. 185), whereas only a very short corresponding branch arises from the left hydroecial trunk. No variant from this basic type was found among the many bracts examined from the Monterey collection, which agrees with the *Albatross* series in this respect. But there is some variation, even in bracts of equal sizes, in the relative lengths of the chief trunks, and in the degree to which these give off short lateral spurs. Thus bracts were noted in which the dorsal trunk sends out one, two or no such spurs; the apical trunk one or none; the left hydroecial trunk one or none in its course over the face of the hydroecium. The length of the dorsal trunk is also variable; in some bracts it runs merely to the dorsal margin, there to terminate; in most cases, however, it then bends to continue inferiorly for a short distance (Fig. 185). In none of the Monterey bracts does it extend as far in that direction as was the case in the example figured from the *Albatross* series (Bigelow, 1911 a, *pl.* 3, *fig.* 6), nor does the right hydroecial trunk recurve. But in view of the variability so commonly seen among siphonophores in this respect, such a difference is not incompatible with reference of the Monterey and Tropical Pacific bracts to the one species.

Another interesting instance of variation is to be seen in the fact that while the right hydroecial wall is considerably the wider in most bracts, a few specimens were found in which the reverse was true, a difference probably associated with the conditions of crowding during the growth of the individual bracts.

The most interesting feature of the groups of the appendages is that search of several segments of stem, and of the mass of damaged gonophores, bracts etc. in the several tows that yielded this form off Monterey, failed to reveal any special swimming bells. Consequently it is safe to conclude that this species lacks such structures, and differs correspondingly from *Stephanophyes*, where they are prominent features of the colony (Chun 1892).

The largest number of gonophores counted in any one stem-group (identified as such by having only one bract and one siphon) was nine, four of these female, five male. Among the material are many detached gonophores of both sexes in various stages of growth. Both the male and the female sex bells are medusi-

form, with well developed radial- and ring-canals. But the subumbral musculature is much more strongly developed in female bells than in male. Furthermore, every female gonophore examined showed a slight asymmetry of the sort

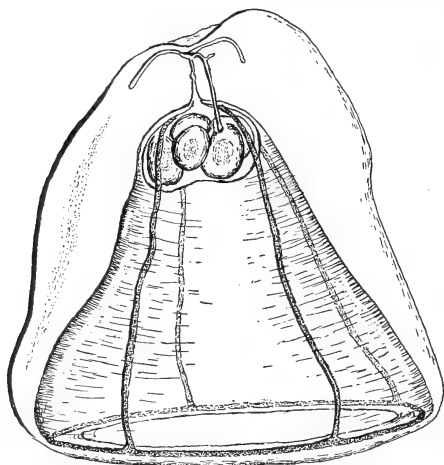


Fig. 186. *Praya reticulata*; female gonophore,  $\times 4.7$ ; from offspring of Monterey Bay, California.

illustrated (Fig. 186). Female gonophores grow to a much larger size than males, the largest of the former measuring about 13 mm., in bell height largest male only about 7 mm. (Fig. 187.)

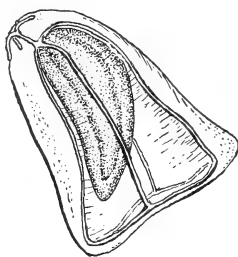


Fig. 187. *Praya reticulata*; male gonophore,  $\times 4.7$ ; from offspring of Monterey Bay, California.

A distinctive feature in gonophores of both sexes is a trifold branching of the pedicular canal at its point of junction, with the three branches extending outward centrifugally over the apex of the bell. No other Prayid, of which the gonophores have been described, shows this arrangement.

In the female bells the manubrium is entirely filled with 4-6 large eggs (fig. 186). The number of these egg-masses that were found detached, as well as of empty bells that had lost all but the base of the manubrium, suggests

that the clusters of eggs are normally shed *en masse*. In the male bells the manubrium is of the usual form (Fig. 187), a sexual difference common among siphonophores.

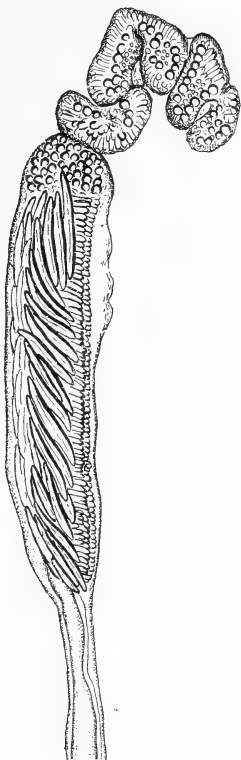


Fig. 188. *Praya reticulata*; young tentillum,  $\times 72$ ; from offing of Monterey Bay, California.

Sketches are given of a young and of an adult tentillum (Figs. 188, 189) from the same tentacle because those of *Praya*<sup>4</sup> have not previously been illustrated. I may note in passing that the curious mouthless siphons and tentacles that are characteristic of Stephanophyes do not occur in *Praya*.

Previous records of the nectophores of this species are Eastern Tropical Pacific off Peru (2 stations), and south of Japan (1 station), by the *Albatross*. Bracts and stems have also been taken off Monterey, California, as just stated, and in Puget Sound (in collection of Museum of Comparative Zoology). The *Arcturus* records are all from the Galapagos-Panama region. Thus, if my identification of the loose stems and bracts is correct, this species is generally distributed over the warm temperate Pacific.

<sup>4</sup> For accounts of those of allied Prayids see Haeckel 1888 a, Chun 1892, Schneider 1899.



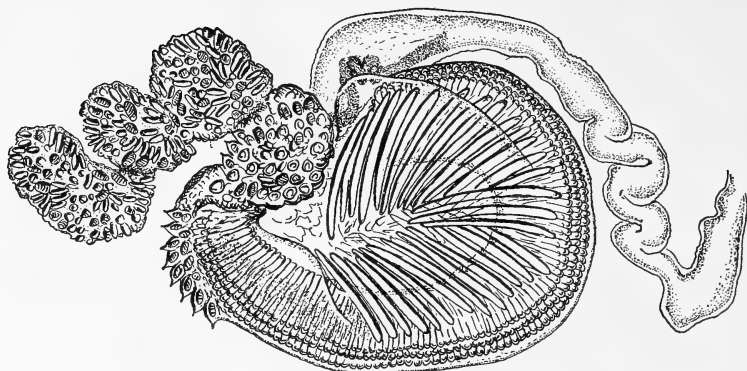


Fig. 189. *Praya reticulata*; adult tentillum,  $\times 72$ ; from same tentacle that bore the young tentillum illustrated in Figure 188.

*Prayinae* (species ?).

Seven nectophores, apparently referable this family, but too fragmentary for generic or specific determination, were taken at Station 11, surface, Station 29, 250–0 meters; Station 50, 727–0 meters; Station 59, 1090–0 meters, and Station 97, 820–0 meters.

Family HIPPOPODIIDAE K  lliker (1853).

Moser (1925) prefers the name Polyphyidae Chun (1882) for this family. But as Haeckel's genus Polyphyes is doubtless a synonym of Hippopodius (Moser herself so classes it) the international rules of zoological nomenclature forbids the use of a family designation derived from it.

According to the latest general classification, this family is monotypic, for Moser (1925) unequivocally unites *Hippopodius* and *Vogtia* (genera that had long been treated as distinct) on the ground that the character on which generic separation has usually been based (form of the nectophore) is a specific one. But this union obscures the fact that *Hippopodius* and *Vogtia* are separated by a much more significant character, i. e. the tentilla (Bigelow 1918, p. 403). The two genera are therefore considered here as distinct though this course entails uncertainty when it is a question of relegating loose nectophores to the one genus or to the other.

*Hippopodius hippopus* (Forsk  l).

*Gleba hippopus* Forsk  l, 1775, p. 14, 1776, pl. 43, fig. E.

For synonymy, see Bigelow, 1911 b, p. 208, and Moser, 1925, p. 409 ("Hippopodius luteus").

Moser (1925), like Lens & Van Riemsdijk (1908), uses the specific name

*luteus* Quoy & Gaimard for this well known Siphonophore. But there seems no doubt that the animal described by these French zoologists was identical with the detached bell that Forskål had described and pictured in 1775-76 as *Gleba hippopus*. The ordinary rules of nomenclature therefore require that *hippopus* be employed as the specific name, as pointed out by Schneider (1898) and by me (1911 a). Recent authors, generally, have accepted Chun's (1897) and Schneider's (1898) view that *Hippopodius* Quoy & Gaimard should be used as the generic designation, rather than *Gleba* Forskål, of checkered history. And no good purpose would be served by re-opening the question at this late date.

Variously fragmented colonies, and loose bells of this species were taken at the following stations: 11, surface; 18 depth ?; 29, 250-0 meters; 41, surface; 45, 363-0 meters; 49, 365-0 meters; 84, 1274-0 meters; 86, 909-0 meters; 87, 1090-0 meters; 96, 2181-0 meters; 98 depth ? 102, surface; 107, 1454-0 meters; 113, 1636-0 meters.

The general morphology of *Hippopodius* is now so well known that nothing is added by this material, for the bells alone remain, whether loose, or still connected. Fortunately, however, for the zoogeographer, these are so firm, and so characteristic in outline, that they are among the most readily recognized of siphonophore-units.

The localities of capture are generally dispersed over the whole route of the *Arcturus*, e. g. between Cuba, Bermuda and the continental edge off Cape Hatteras; likewise the Sargasso Sea to the southeast of Bermuda in the Atlantic; and the Galapagos-Cocos Island-Panama region in the Pacific.

These records provide cumulative evidence that *Hippopodius hippopus* is cosmopolitan in the warmer belts of the high seas, and thence northward and southward in their current-extensions. Like most siphonophores, however, it is highly sporadic in its appearance, and has failed to appear in some collections from regions where it might have been expected.

So far as known it is not at home in any of the extensions, equatorward, of sub-arctic or sub-antarctic waters, or in coast water subject to extreme winter chilling; hence its absence from the continental shelf off the eastern United States, and from the North Sea region.

The comparative scarcity of *H. hippopus* in *Arcturus* surface hauls, contrasted with its strong representation in deep tows with open nets, is in line with the captures by the *Albatross* (Bigelow 1911 a), *Gauss* (Moser 1925), and *Bache* (Bigelow 1918). Moser (1925) has already remarked on its considerable vertical range, and on its comparative tolerance to varying temperature that this implies.

*Vogtia spinosa*, Keferstein & Ehlers.

*Vogtia spinosus*, Keferstein & Ehlers, 1861, p. 24, pl. 5, figs. 16, 17, Chun, 1897, p. 103; Bigelow, 1911 a, p. 210, pl. 15, figs. 5-12, 1913, p. 68, fig. 1. *Vogtia köllikeri*, Haeckel, 1888 a, p. 182, pl. 29, fig. 9-14. *Hippopodius spinosus*, Moser, 1925, p. 419.

Detached bells, showing the characteristic spination of this species on the facets as well as on the ridges, were taken at stations 29, 250-0 meters; 33, 1274-0 meters; 38, 545-0 meters; and 59, 272-0 meters.

These nectophores agree closely with the more extensive material collected

by the *Albatross* in the same general part of the Pacific in 1904-1905. Moser (1923, p. 43) states that she has found that *V. spinosa* is identical with *V. pentacantha* Kölliker (1853). In that case the former name becomes (by the rule of priority), a synonym of the latter. On this point I can express no opinion, having seen no intermediate specimens. And since Moser (1925) retains both species in her account of the *Gauss* collection, the same course is followed provisionally here.

*Vogtia serrata* Moser.

*Hippodius serratus* Moser, 1925, p. 420, pl. 27, figs. 6-8, pl. 28, figs. 4-9.  
 [*Vogtia serrata* Moser, 1913, p. 149, no description of figures.]  
*Vogtia pentacantha*, Moser, 1912, p. 329; Bigelow 1913, p. 66, pl. 5, figs. 7-9, pl. 6, fig. 6.  
 [non *V. pentacantha* Kölliker.]

Station 33, 1274-0 meters; one adult nectophore.

This bell, sufficiently preserved to show its characteristic shape, agrees so closely with the *Vogtia* described by me (1913) from the Northwestern Pacific as *V. pentacantha*, but which, as Moser (1925) points out, was almost certainly her *V. serrata*, that I have no hesitation in identifying it as such.

The only respect in which it differs from Moser's (1925) account is in the fact that its angles—at least in its present flabby state—are smooth, not denticulate. But in view of its poor condition, and of the variability of denticulation among Calycophorae in general, this does not warrant separating it, or the specimens from the Northwestern Pacific (these likewise were smooth) from *serrata*.

? *Vogtia serrata*, Moser.

Five loose nectophores, from station 61, 1090-0 meters, are provisionally referred to this species, because they entirely lack the large conical gelatinous spines so characteristic of *V. spinosa* and of *V. pentacantha*. Furthermore, one of these bells shows slight traces of denticulation in places along the angles separating the facets, agreeing in this with Moser's (1925) account and illustrations, though for the most part the angles are smooth; wholly so in the best-preserved example (fig. 190). Further evidence that their closest affinity is with *serrata* is afforded by the form of the ventral sinus, for in the only one in which this can now be traced, it is narrow-linear, (cf. fig. with Bigelow, 1918, pl. 5, figs. 7-9), without the lateral expansion characteristic of *V. spinosa* and of *V. pentacantha*.

The only reason for hesitation in referring these bells to *serrata* is their peculiarly elongate outline, with pyramidal apex (fig. 190) much more prominent than in any *Vogtia* previously described.

This feature, however, must be classed as of little systematic significance, unless some discontinuity can be shown between bells of this form, and those of the same general character but less elongate in outline.

If the identification of these bells be correct, the records are interesting, geographically, as extending to the Eastern Tropical Pacific the known range of the species (mid-Atlantic; Tropical Indian Ocean; Subantarctic; Northwest Pacific; Bering Sea; Sea of Okhotsk; Japanese and Chinese waters), corroborat-

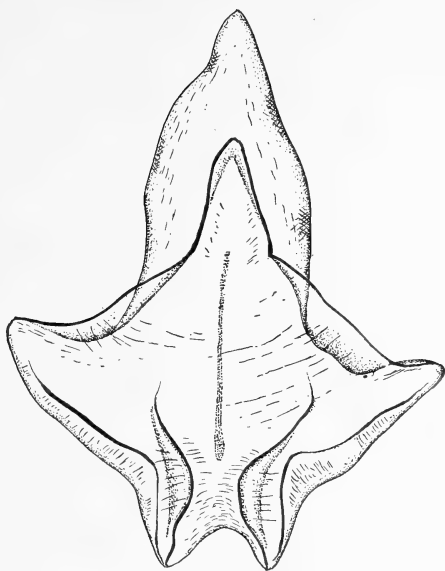


Fig. 190. *Vogtia serrata* ?; nectophore in ventral view,  $\times 3.3$ ; from Arcturus Sta. 61.

ing Moser's (1925, p. 421) classification of it as "Kosmopolit im weitesten Sinne des Wortes."

Family DIPHYIDAE, Quoy & Gaimard 1827.

In earlier papers (1911 a, 1913, 1918) I credited this family to Eschscholtz (1829). But as Huxley (1859), and recently Moser (1925, p. 125) point out, it was in fact set up by Quoy & Gaimard in 1827, in their preliminary report on the Medusae and Siphonophores, collected by the *Astrolabe* in the Straits of Gibraltar. For an interesting account of the history of the family, see Moser (1925, p. 127).

The *Arcturus* collection contains representatives of five sub-families of this family—Abylinae, Ceratocymbinae, Galettinae (Galeolarinae, auct.), Diphyinae and Chuniphyinae. The first two of these groups call for no special discussion. The third has usually been named Galeolarinae. But Stechow (1921) has pointed out that this name can not be used for Siphonophores because the generic name *Galeolaria* was preoccupied by Lamarck (1818) for a worm. As substitutes, for the Siphonophores in question, he has proposed *Galetta* and Galettinae.

Most students agree in recognizing Galettinae as one of the major subdivisions of the Diphyidae; but different diagnoses, by Moser (1925) and by me, result in different allocations of certain of the species concerned. As is so usually the case, successive studies progressively clarify the situation.

In earlier papers (following Chun) I considered permanent attachment of the stem-groups as one of the alternative characters separating Galettinae from Diphyinae. To this Moser (1925) objects that Lochmann's (1914) observations on the development of *Galetta quadrivalvis* show that even in this typical *Galetta* the stem-groups do become detached, to live independent for a period of 8-14 hours during the final ripening of the sex products.

Thus no sharp line can be drawn between the typical Diphyinae, in which the stem-groups carry on a protracted independent existence after breaking free, with their bracts undergoing a progressive development, producing meantime a succession of gonophores, and the opposite extreme (if such does indeed characterize any actual *Galetta*) in which the stem-groups remain permanently attached to the stem.

But the contrast between the states illustrated in this respect by *Galetta quadrivalvis* on the one hand, and by *Diphyes* on the other, is more significant than a mere difference in the duration of the period of free existence for the stem-groups would be. Furthermore, no sharper line can be drawn in any other respect between Galettinae and Diphyinae. Thus while the bells of the more typical members of the former are rounded, contrasting with the strongly pyramidal bells with well marked angles of the latter, several species, e. g. *truncata*, bridge the gap between these two categories, for their rounded bells show slightly marked angles. Such species have been referred sometimes to the one genus, sometimes to the other. Similarly, no definite distinction can be drawn between species in which the bells are firmly connected and those in which they are loosely attached one to the other. Neither is the presence or absence of an hydroecium any more precise as an alternative character, because in some species it is represented by a shallow furrow or indentation of the base of the superior nectophore; thus Moser (1925) mentions a shallow hydroecium as characteristic of her "Formenkreis III" of *Galetta*, though in general she considers the absence of an hydroecium as diagnostic of the genus.

We face here one of those cases (the bane of the systematist) where two groups of species, though differing so widely in several morphological respects that they are separable at a glance, are connected by intermediate forms. And when, of necessity, we deal with characters that are not strictly alternative (unless new diagnostic features be found that have so far been overlooked) no definitions can be drawn so definite but what it may always be an open question to which group certain of the intermediate species are best referred. In the present case the form of the inferior nectophore (with simple groove-like hydroecium in Galettinae which is more or less completely bridged in Diphyinae) may prove more diagnostic than that of the superior nectophore.

Recent authors differ as to whether the known species of the subfamily Diphyinae represent one genus, *Diphyes*, or two, *Diphyes* and *Diphyopsis*: final decision will govern the choice of name for the subfamily. Most students, since Huxley (1859) have recognized the two genera, believing that the presence or absence of special swimming bells in the stem-groups is a proper generic character rather than a specific one.

Schneider (1898), however, and latterly Moser (1925) recognize only the one genus, *Diphyes*. This course is certainly the more convenient in practice, because specimens (as taken) have usually lost the stem, hence could not be referred to the one category or to the other by a character shown only by the stem-groups. And it has repeatedly happened in the past that a new Diphyid has been described that could only provisionally be given a generic name for this reason.

A recent survey of the history of this group also shows that to recognize two genera, one with, the other without special nectophores in the stem-groups, would require the resurrection of a long forgotten name for some of the best known of all siphonophores; there seems no escape if the ordinarily accepted rules of nomenclature, embodied in the International Code, are to be followed.

The first Diphyid to appear in zoological literature was the "*Biphore bipartie*, *Salpa* (bipartita) *lanceolata bipartita*" of Bory de St. Vincent (1804), for which Cuvier 1817, p. 61) set up the genus *Diphyes*. As Bory's name was not binomial, the type species of *Diphyes* must always remain the *Diphyes dispar* of Chamisso & Eysenhardt (1821). Haeckel (1888 a), however, when he split

*Diphyes* into two genera (the one with, the other without the special nectophores) did not give the new name to the category that differs from *dispar* in this respect, but placed *dispar* itself in his new genus *Diphyopsis* together with two supposedly new species (*canpanulifera* and *compressa*) that are now known to be synonyms of it. The generic name *Diphyopsis* is therefore a synonym of *Diphyes*, and all species that agree with *dispar* must be referred to *Diphyes*.<sup>5</sup>

Therefore if two genera are to be distinguished, those which differ from *dispar*, in lacking special nectophores, must be removed from *Diphyes*, not those that agree with *dispar*, and a name must be found for them.

On running through the synonymy of the several species in question, we find that the only available generic name (*Diphyes*, *Eudoxia* and *Cucullus* having been proposed first for the nectophores or for the eudoxids of *Diphyes*, proper) is *Eudoxoides*, given by Huxley (1859) to a loose bract so characteristic in outline that Moser (1925) has been able to identify it as belonging to *Diphyes mitra*, which, as she has proved on extensive material, has no swimming bells in its stem-groups.<sup>6</sup>

But revival of this name for the category of species so characterized (*Diphyopsis* must be abandoned in any case), entails the removal, to it, of all the species that most recent authors have called *Diphyes*, and the relegation to *Diphyes* of all the species of the defunct genus *Diphyopsis*.

In short, we come to this:—continued recognition of two genera in this subfamily will cause increased nomenclatural confusion in a group where such confusion has too long been rife; in actual practice great inconvenience will result. On the other hand, to recognize only one genus will conceal the fact that the species concerned fall into two major categories, the members of each of which differ among themselves by other characters.

In reaching a decision in such a case weight may fairly be given to the essential difference between the ideas that we mean to express by the names species and genus. To the taxonomist the species is the nearest known approach to a basic unit or integer; a genus on the contrary is, in essence, a subjective concept, for it will always be

<sup>5</sup> I had overlooked this situation in my earlier discussions of the subfamily.

<sup>6</sup> The bud interpreted as such by Lens & Van Riemsdijk (1908) was in reality that of a gonophore.

a matter of opinion how species should be grouped, with changes in viewpoints as to the relative importance of given characters often leading to rapid generic realignments. While in the present case it might seem that the presence or absence of special swimming bells is more significant than the conformation of the bell, or the arrangement of the ridges etc., we have no assurance that within a few years the opposite view may not prevail. On the whole it seems that in the case in question systematic presentation of the Siphonophores will be best served by regarding all these characters as specific, i. e. by including the two categories in question within the one genus, *Diphyes*.

The discontinuity and anatomical precision of the structural features that separate species within this genus make them easy of identification. Keys for that purpose are given by Moser (1925, p. 169) and in my account of the *Albatross* Siphonophores (1911 a, p. 246).

*Abyla leuckartii* Huxley.

*Abyla leuckartii* Huxley, 1859, p. 49, pl. 3, fig. 2.

For synonymy and description of the polygastric generation, see Bigelow, 1911 a, p. 216, pl. 13, figs. 5-8; Moser, 1925, p. 288, pl. 17, figs. 4-6.

Station 11, surface, five superior nectophores and one fragmentary gonophore.

? Station 29, depth? one bract.

The bract listed above is referred to *A. leuckartii* because it conforms to the other bracts, bearing gonophores of the *leuckartii* type, that I have previously seen (p. 549, 1918); i. e. the asymmetrical ridge joins the apical ridge, while the apical facet is hardly convex. But the bracts of this species so closely resemble those of *Ceratocymba sagittata* that a loose example of this type can never be identified positively.

The eudoxid of *A. leuckartii* seems first to have been described in 1908, but without knowledge of its parentage by Lens & Van Riemsdijk, who recorded, under the specific name *asymetrica*, a new eudoxid with bract of the *Ceratocymba* type, in which the baso-ventral teeth of the gonophore were about equal in length, while the baso-dorsal teeth projected but little beyond the dorsal outline of the bell. This combination of characters positively identifies this eudoxid as belonging to *A. leuckartii*, for it is now known that this basal conformation is not only characteristic of the latter, but very sharply marks it off from the eudoxid of *Ceratocymba sagittata*, where one of the ventro-basal teeth is greatly elongate, while the dorso-basal tooth projects (p. 548).

Moser (1925, p. 269), it is true, relegates the *C. asymetrica* of Lens & Van Riemsdijk to the synonymy of *Ceratocymba sagittata*. But the outlines of the gonophore are so distinctive in this case, that Lens & Van Riemsdijk's illustration of it (1909, pl. 1, fig. 5) is quite sufficient to demonstrate its identity as *leuckartii*, the eudoxid of which is now well known.



All other *Ceratocymbas* that have been described, belong to *Ceratocymba sagittata* (p. 548). This includes the *Ceratocymba sagittata* of Bedot (1904) as Moser (1925) has pointed out, for while Browne (1926, p. 66) objects that the bract in Bedot's figures is symmetrical, I have myself seen specimens in which the asymmetrical ridge might easily be overlooked.

The structure of the very characteristic nectophores of *A. leuckartii* has been described and figured in such detail by previous writers that the few examples in the *Arcturus* series could not be expected to add to our knowledge of the morphology of the species, especially since all of them have lost all but the basal part of the stem.

Moser (1925) considers it likely that the gonophores of the two sexes are mirror pictures one of the other, as is the case in *Ceratocymba sagittata*. But determination of this point must await examination of male gonophores, the female bell of *leuckartii* alone having been studied so far (Bigelow, 1918, Pl. 6, fig. 4).

The *Arcturus* captures are from general regions (mid-Atlantic; and between Panama and the Galapagos) where *A. leuckartii* had already been reported. While this species is one of the less frequent Abylids, its reported captures show it to be general in the warmer belts. Thus it has been taken in the eastern tropical Pacific, in Australian, Malaysian and Philippine waters, in the tropical Indian Ocean; also among the West Indies, and at widely separated localities in the North and South Atlantic.

*Abylopsis tetragona*, Otto.

*Pyramis tetragona*, Otto, 1823, p. 306, pl. 42, figs. 2 a-2 e.

For synonymy, see Bigelow, 1911 a, p. 224; Browne, 1926, p. 63; ("Abylopsis pentagona"); Moser, 1925, p. 320.

This well known species was taken at Stations 15, 29, 33, 38, 39, 45, 49, 53, 74 and 84, in 18 different tows, from depths ranging between 250-0 and 1274-0 meters; all in open nets. The material consists of upwards of 35 colonies, 25 inferior nectophores, and a single loose gonophore. The collection contains no complete eudoxids, and no loose superior nectophores: probably these were overlooked in the sorting of the plankton on shipboard.

Most of the specimens are more or less fragmentary—many of them extremely so. There is, however, no danger of confusing the inferior nectophores of this large Abylid with those of any other species. Its superior nectophore (figs. 191-192) closely resembles that of *A. eschscholtzii*: so closely in fact that Moser (1925) considers them indistinguishable. They can, however, be separated by minor characters, at least in most cases, as I have previously suggested (1911 a), and as Browne (1926, p. 64) has recently shown. For discussion of this point, see page 546, under *A. eschscholtzii*.

*A. tetragona* has so often been described and figured, and it is in general so well known morphologically, that the present series could not be expected to add materially to the earlier accounts, except by way of confirmation.

Although this is no doubt the most familiar member of its family, opinion is not yet unanimous as to the correct specific name for it. Hence it seems necessary to restate my reasons for following Schneider (1898) in reviving Otto's name *tetragona*.

Admittedly Otto's (1823) description and illustrations are so inaccurate that, of themselves, they would not suffice to identify them with any actual Siphonophore. But they do satisfy the requirements of Article 25, of the International Code of Zoological Nomenclature, that a name be "published and accompanied by an indication, or a definition, or a description." Consequently, *tetragona* can not be regarded as a nomen nudem, to be relegated to oblivion.

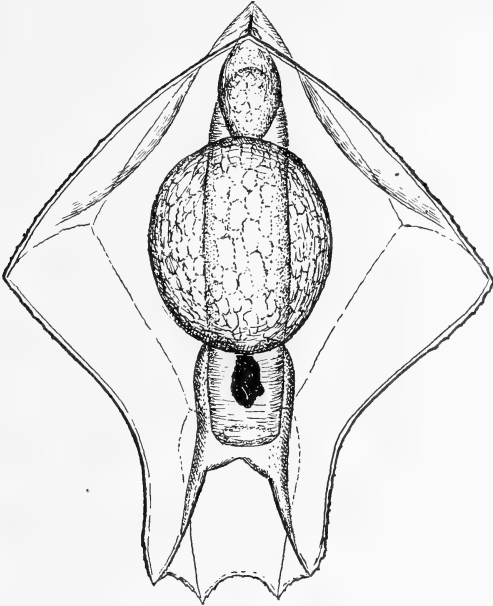


Fig. 191. *Abylopsis tetragona*; superior nectophore, ventral view,  $\times 10$ ; from Arcturus Sta. 49.

In 1897 Chun pointed out that Otto's specimens were still preserved in good condition in the Breslau Museum, and by personal examination he was able to establish that they belonged to the species that authors had called *pentagona*, following Quoy & Gaimard (1827) and Eschscholtz (1829). Chun, however, did not revise Otto's (the oldest) name, quoting in justification, section 6 of the code of nomenclature of the German Zoological Society, which provided that a name in general use was not to be superseded by an older one not referable to a definite systematic unit. But as Schneider (1898, p. 89) showed, *tetragona* was removed from this unidentifiable category by Chun's own identification of its type specimen. Consequently modern zoological usage demands the substitution of *tetragona* Otto for *pentagona* Quoy & Gaimard, no matter how misleading the original account of *tetragona* may have been.

The *Arcturus* records are from general regions where *A. tetragona* was already known to be widespread; probably as regularly occurrent as is any

siphonophore. It is interesting, however, and hard to explain, that none of the specimens came from surface tows. Nor can it be supposed that it was represented in the latter, but overlooked in the sorting of the catches, being

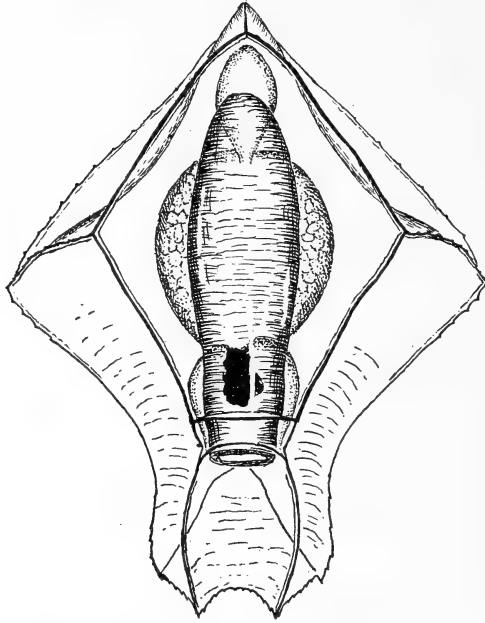


Fig. 192. *Abylopsis tetragona*; superior nectophore, dorsal view of specimen illustrated in Figure 191.

far too conspicuous an object. *Tetragona* was also taken most regularly in deep hauls in the Eastern Tropical Pacific on the *Albatross*, only occasionally at the surface. But the *Bache*, in the northwest Atlantic had it more frequently at the surface; likewise the *Gauss*, and earlier collections. One must then be cautious in referring a species to the bathyplankton on the basis of a single collection.

*Abylopsis eschscholtzii*, Huxley.

*Aglaismoides eschscholtzii*, Huxley, 1859, p. 60, pl. 4, fig. 2.

For synonymy, description, and general discussion, see Bigelow, 1911 a, p. 226; Moser, 1925, p. 334; Browne, 1926, p. 65.

Station 84, surface, one pair of nectophores united, also 9 loose superior and 29 inferior nectophores.

Station 87, 1090-0 meters, 2 superior, 9 inferior nectophores.

Station 98, 1500-0 meters, one inferior nectophore.

There is no danger of confusing the inferior nectophores of *A. eschscholtzii* with those of any other species. According to Moser (1925, p. 338), the superior nectophore resembles in all respects that of *A. tetragona*, and so far as general form, shapes of the facets, etc. is concerned, this is certainly the case. In most instances, however, it is possible to relegate a given nectophore to one or to the

other species, by minor characters. I have already suggested that the course of the subumbral canals (highly arched in *tetragona*) would prove diagnostic, and Browne's (1926) subsequent studies, with my own, have proved that this type is usually characteristic of that species, but apparently never occurs in *A. eschscholtzii*.

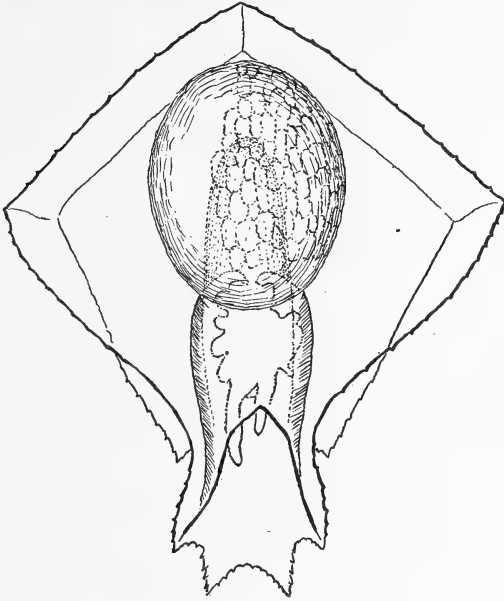


Fig. 193. *Abylopsis eschscholtzii*; superior nectophore, ventral view,  $\times 15$ ; from *Arcturus* Sta. 84.

Some examples, however, as he found, show a state intermediate between the extremes figured by me (1911 a, *pl.* 14, *figs.* 1, 6), and therefore could not be placed on this basis alone, if separated from their very diagnostic lower nectophores. But he has pointed out that another difference may be depended upon, in all but an occasional example, for the apex of the nectosac extends apically beyond the main body of the somatocyst in *tetragona*, but falls short of it in *eschscholtzii*.

Fresh examination of specimens of each, in which both nectophores are still connected, making their identity certain (Figs. 191–194), confirms his conclusions. And it is by this criterion that the loose superior nectophores listed above from the *Arcturus* series are referred to this species. Rarely, a loose nectophore may be found so nearly intermediate in all respects that its identity, as the one species or the other, cannot be determined.

The inferior nectophores listed above agree, even to minute details, with the earlier accounts.

The *Arcturus* localities are near the Galapagos, and in the Atlantic near

Bermuda; regions where this species has already been taken by the *Albatross*, and by the *Bache*. This is one of the commoner species of its group, widespread in warm oceans. It has not been recorded as yet from the Mediterranean, but

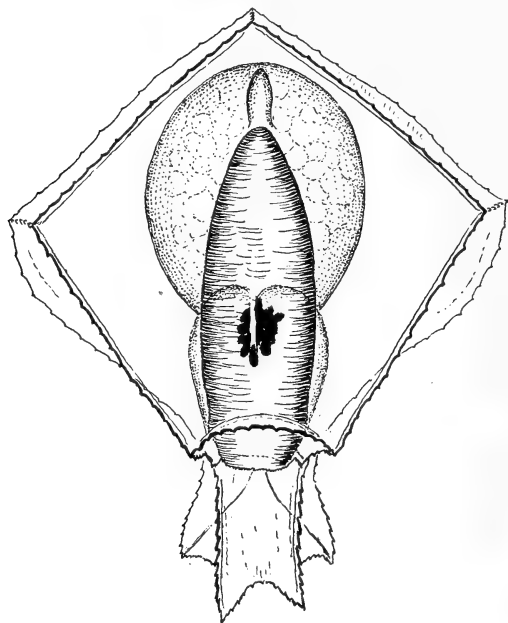


Fig. 194. *Abylopsis eschscholtzii*; superior nectophore,  $\times 15$ ; dorsal view of specimen illustrated in Figure 193.

in view of Moser's (1925) recent capture there, of several siphonophores previously known only from the open oceans, it is not safe to assume that *A. eschscholtzii* will not equally be found within the Mediterranean, when the siphonophore-fauna of the latter has been examined more intensively.

*Bassia bassensis*, Quoy & Gaimard.

*Diphyes bassensis*, Quoy & Gaimard, 1834,<sup>7</sup> p. 91, pl. 7, figs. 18-21.  
For synonymy, see Bigelow, 1911 a, p. 220; Moser, 1925, p. 347.

Station 45, 7 eudoxids all much crumpled.

Station 97, 1000-0 meters, two superior nectophores, all much crumpled.

This scattering representation of this well known form calls for no special comment, as it is generally distributed and often reported in the warmer belts of all the oceans.

*Ceratocymba sagittata*, Quoy & Gaimard.

*Cymba sagittata*, Quoy & Gaimard, 1827, pl. 16, pl. 2 C; figs. 1-9.  
For synonymy, see Bigelow, 1918, p. 411, 412; Moser, 1925, p. 269.

<sup>7</sup> This paper, with the accompanying plates, is dated "1833." But according to Sherborn & Woodward (1901) it did not appear until 1834. And this date is accepted in the catalogue of the British Museum.

This species was taken at stations 17, 29, 38, 96, 98 and 108, in hauls varying in depth from the surface to 2181-0 meters. The material consists of seven superior nectophores, 9-26 mm. long, one inferior nectophore 39 mm. long, two bracts 16 and 20 mm. long, and one male gonophore, 25 mm. long.

The superior nectophore of this species, though among the most easily recognized of all Calycophorae, was not seen until 1908 (Lens & Van Riemsdijk, as "*Diphyabyla hubrechtii*"). But both the inferior and the superior bells have been described so fully since then, at different stages in growth, and pictured in such detail (Bigelow 1911 a "*Diphyabyla hubrechtii*," p. 231, pl. 12, fig. 7; 1918, p. 7, fig. 1; Moser, 1912 a, fig. 23; 1925, p. 274, pl. 15) that no additional account is needed here. The *Arcturus* specimens agree with those of corresponding sizes of which accounts have already appeared.

The bracts of the free eudoxid of *Ceratocymba* so closely resemble those of *Abyla leuckartii* that Moser (1912 a, 1925) describes them as indistinguishable, though the gonophores are easily distinguishable, their basal teeth being symmetrical in *A. leuckartii* but strongly asymmetrical in *Ceratocymba* (Bigelow 1918, pl. 6, figs. 3-4, pl. 7, figs. 2-3; Moser, 1925, Pl. 16, figs. 2-5, Totton, 1925). In the eudoxids that I have seen with gonophores of the *Ceratocymba* type, the asymmetrical (left lateral) ridge of the bract fails to reach the apical ridge, and the apical facet is strongly concave. On the other hand, in the only eudoxid of *leuckartii* that I have examined (identity established by its gonophore), the asymmetrical ridge joins the apical ridge of the bract, while the apical facet of the latter is nearly flat. This difference is described in greater detail elsewhere (Bigelow, 1918, p. 414).

Here the matter must rest until someone has an opportunity to examine a large series of eudoxids (with gonophores) of the two species.

Meantime, bracts that show the characters just stated are listed here as *Ceratocymba*. The male gonophore listed above, characterized by its asymmetry and by the fact that it is a mirror-picture of the female sex bell in this respect, agrees with the previous accounts and figures.

*Ceratocymba sagittata* was to be expected in the *Arcturus* collection for it had already been reported from the same general regions. The localities of record for it cover widely separated localities in the Indian Ocean, the Malaysian region, the Eastern Tropical Pacific and in the North and South Atlantic where the *Gauss* (Moser, 1925) and the *Bache* (Bigelow, 1918) gathered considerable series.

*Galetta*<sup>8</sup> *quadrivalvis*, Blainville.

*Sulculeolaria quadrivalvis*, Blainville, 1830, p. 126; 1834, p. 138, pl. 6, fig. 6 (Lesueur, mss.).

The synonymies given earlier by Moser (1925, p. 139) also include all references published prior to 1918 to the form recorded by me (1911 a, p. 237) here (p. 556) as *Galetta quadridentata*, Quoy & Gaimard.

Opinions still differ as to whether *quadrivalvis* in which the base of the superior nectophore is bidentate, and *quadridentata*, in which it has four teeth, represent two separate species or whether they are merely the extremes of one varietal range. Solution of this question is, however, needed because almost

<sup>8</sup> *Galeolaria* auct., see p. 539.

all our knowledge of the general organization and development of this group of siphonophores has been drawn from the one or the other of the two.

No difference has yet been found to separate the inferior nectophores of these two forms: both show the two circular constrictions of the nectosac, the four basal teeth, the divided ventro-basal wing, and the complex canal system that has often been described for *Galettia quadrivalvis*. My own examination of the stem-groups of the two, as described below, has equally failed to bring out any points of difference. The superior nectophores also agree in their general form and in the arrangement of their canals; they differ only in the sculpture of the base. But in this respect the two forms differ so widely (considering the reliability of this character in general among Diphyids) that in previous discussion I had no hesitation in referring them to separate species.

A search of the literature shows that both these forms were early recorded, though with no more than passing mention. Blainville's (1830, 1834, p. 138, pl. 6, fig. 6) description and figures of *Galettia* ("*Sulculeolaria*") *quadrivalvis* were based on the inferior nectophore; hence it will never be possible to determine whether it was of the bidentate or quadridentate type. But, simultaneously, Quoy & Gaimard (1834) described and pictured as *Galeolaria quadridentata* a superior nectophore of the quadridentate form; hence my (1918) choice of that name for the latter. Since that time, though one feature or another of this group has been the subject of many discussions, the particular feature in question has been ignored for the most part. The quadridentate form was reported by Keferstein & Ehlers (1861, as "*Diphyes quadrivalvis*"), who describe the superior nectophore as having six points ("*Zipfel*"), two upper, two lower, and one on each side, which clearly refers to the four circum-oral teeth and to the two ventro-basal wings. According to Moser (1925, as "*Galeolaria quadrivalvis*") the mouth of the nectosac is surrounded by four teeth (two dorsal and two lateral) with divided ventro-basal wing. And this same conformation has been described and figured by me (1918) under the name *Galeolaria quadridentata* Quoy & Gaimard.

A bidentate contour was first definitely recorded by Leuckart (1854, p. 280 as "*Galeolaria filiformis*"), who described the "Klappen des vordern Schwimmstücke" as "ein innere und ein ausseres Paare"; and (p. 284) "die Klappen am aussen und innern Rande der vordern Schwimmglocke" as "in der median linie gespalten, also paarig . . ." This evidently refers to paired dorsal teeth, and to divided baso-ventral lamella.

It is also certain that the superior nectophore figures by Lens & Van Riemsdijk (1908, pl. 9, fig. 74) had only dorsal, and no lateral teeth. This was also true of the *Albatross* specimens from the Eastern Tropical Pacific, (Bigelow 1911 a).<sup>9</sup>

My own earlier studies on the *Albatross* and *Bache* material of the two types, show that the extremes are far apart. Moser (1925) however, in the latest pronouncement on the subject, definitely unites them in the synonymy of

<sup>9</sup> Gegenbaur's (1853) description of his *Diphyes quadrivalvis* was apparently based on the bidentate form also, for his account and figure of two pointed projections above and below the bell-opening is not compatible with the presence of lateral teeth. Vogt (1854) seems also to have seen only ventro-basal lamella and the dorsal tooth (or teeth).

the one species *quadrivalvis*, remarking that the dentition is variable, but with no statement as to what range of variability she has actually observed, nor any more direct reference to the bidentate form.

It is certain that further discussion of the earlier accounts can never settle the question whether these two forms, so widely different in one very obvious character, but inseparable (so far as yet known) in all others, are different species, are dimorphic forms of one species, or are merely varieties of the one. The answer can only come by determination (from examination of large series), whether the two types are actually discontinuous, or whether they are connected by intermediate states with lateral teeth varying from well developed to none.

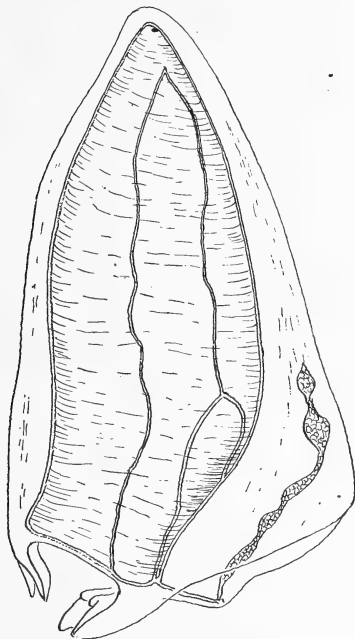


Fig. 195. *Galetta quadrivalvis*; lateral view of superior nectophore,  $\times 4$ ; from *Arcturus* Sta. 87.

Meantime, it is necessary to refer to the two forms in question, either by one specific name, or by two names. In a case of this sort, it is important to emphasize the facts (a) that a difference does exist between two forms; and (b) that reduction of this difference to terms of nomenclature requires investigations of a sort or extent not yet undertaken. In the present report of progress, the two forms are referred to different species, though with the express reservation that this reference is no more than provisional. Browne (1926) also follows this course. Fortunately there is no question of a new name in this case, whatever be the decision, for *quadridentata* Quoy & Gaimard (1834), almost



certainly was based on the quadridentate form in question; while *quadrialvis* Blainville can be applied to the bidentate.

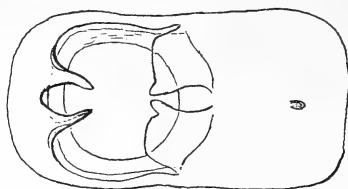


Fig. 196. *Galetta quadrialvis*; basal view of superior nectophore,  $\times 4$ ; from *Arcturus* Sta. 87

Thirty-four superior nectophores of the bidentate type, with two prominent baso-dorsal teeth (figs. 195, 196), and deeply divided ventro-basal lamella or wing were taken at station 87, 1000-0 meters.

Examination of 32 of them gave the following result, with regard to variation:—in 25 the outline of the margin of the bell-rims was uninterrupted from base of dorsal tooth to base of ventral lamella (Figs. 195, 196), with no trace of any baso-lateral tooth or even projecting angle on either side: seven specimens, however, show slight indication of such a tooth opposite each lateral, exumbrial ridge (Fig. 197). But even in the specimen in which this is most pronounced, it is a very minute structure, as contrasted with the lateral teeth of *Galetta quadridenta* (p. 556; Bigelow, 1918, pl. 8, fig. 1, 2). Thus a wide gap remains between the most convergent examples of the two types that have yet been actually recorded: a gap that future investigation may, or may not bridge.

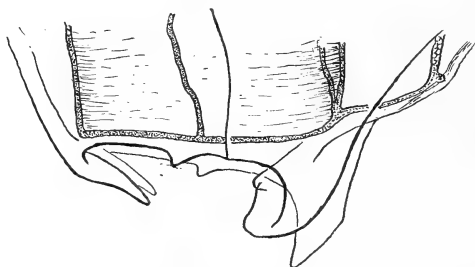


Fig. 197. Lateral view of base of superior nectophore of specimen showing lateral marginal angles,  $\times 6$ ; from *Arcturus* Sta. 87.

Moser (1925) has already, and justly, made use of the courses of the sub-umbrellar canals and of their anastomoses as specific characters within this genus. So far as I can learn, none of the earlier illustrations show those of *Galetta quadrialvis* in an altogether satisfactory way, Fewkes' (1879 pl. 3, fig. 4) picture being the most illustrative. An illustration of one of the present series is therefore given in figure 195. As Moser points out, the superior nectophore of *quadrialvis* agrees essentially in this respect with that of *Galetta australis*, and of *Galetta monoica*, all of them being characterized by the presence

of a commissure connecting the ascending branch of the looped lateral canal with the ventral canal (c/f Fig. 195 with Bigelow 1911 a, *pl.* 6, *figs.* 1, 2, 5, 8). The chief difference is that while in *G. quadrivalvis* and in *G. monoica* the ascending lateral trunk arises close to the union of pedicular canal with subumbral system, in *G. australis* it arises from the ring-canal at some distance from this point.

Forty-two inferior nectophores taken in the same haul, need no special comment: they agree in every respect with the earlier accounts. Had they been taken alone, they might equally have been referred to *Galetta quadridentata*. But since they were gathered side by side with superior nectophores of the bidentate type, in a haul which yielded none of the quadridentate type, their connection with the former seems assured.

Unfortunately all but the base of the stem has been lost in every case, consequently the present series adds nothing to previous knowledge of the cormidia. But as Moser (1925) has recently emphasized the interest that attaches to the reserve-bells that various authors have described in this species, it is worth remarking that one of the *Albatross* specimens shows two such buds—both at an early stage in development (Fig. 198). Each bud, furthermore, is attached to the base of the stem by a structure corresponding to the larger pedicular attachment which bore the two large nectophores.<sup>10</sup> By their location and relation to the large bells, these young bells, with those described below (*p.* 556) for *Galetta quadridentata* answer Moser's (1925, *p.* 141) question "wie und wo die Ersatzglocken entstehen und sich entwickeln."

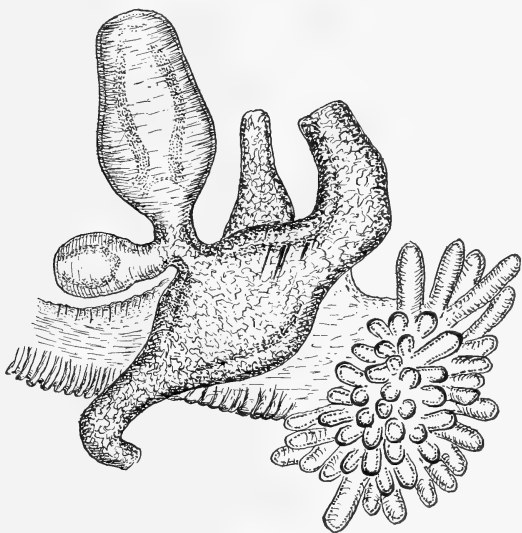


Fig. 198. *Galetta quadrivalvis*; basal part of stem of specimen showing two reserve buds,  $\times 40$ ; from Arcturus Sta. 87.

<sup>10</sup> These were joined together, when the specimen was taken.

The presence of a fourth pedicle (Fig. 198), intermediate in size, suggests that in life the colony had borne still another and larger reserve bud, though this had become detached before the preserved material was examined. Owing to the contracted condition it is not possible to determine how far the pedicles which bore the two large nectophores extended to either side of the axial canals; the present state, as shown in the sketch (Fig. 198), may therefore be misleading in this respect. We have still to learn whether the successive detachment of large bells, and their replacement by small, described by Gegenbaur (1854), and by Korotneff (1884) who observed the event in specimens living in aquaria, is the normal process, as it seems to be in some Prayids, or whether the reserve-bells play that role only when one or other of the chief bells has been accidentally lost. Gegenbaur's (1853) observation that while most of the reserve-bells show the incipient characters of inferior nectophores, occasionally (when four such buds were present), one showed the characters of a superior nectophore, seems to support the first alternative.

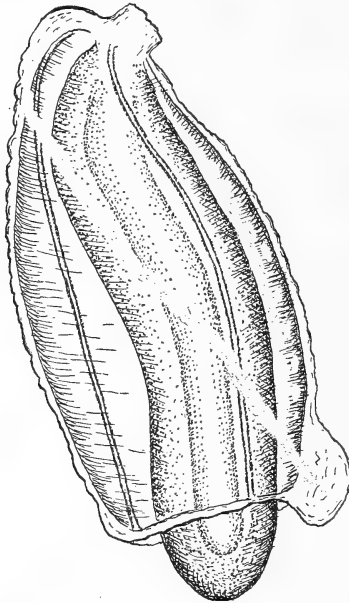


Fig. 199. *Galetta quadrivalvis*; male gonophore,  $\times 70$ .

For accounts of the stem-groups of *Galetta quadrivalvis* (this, with *quadridentata* is the only member of the genus, the cormidia of which have been adequately described), we must turn back to Vogt (1854), Leuckart (1854), Gegenbaur (1853), and Schneider (1896, 1898). These descriptions are in essential agreement as to the simplicity of the bracts; the general structure of the tentilla; the fact that each stem-group bears but a single gonophore; and as to the disparity in size and appearance between the male and female sex bells.

Moser (1925, p. 144) points out certain slight disagreements among the early accounts as to form and canalization of the bracts, and as to external sculpture of the gonophores. The bracts of the *Albatross* specimens, though much crumpled after twenty-five years preservation, still show the conical bases described and figured by Vogt (1854) and by Gegenbaur (1853). But in their present state it is impossible to determine whether, or not, they had the very stout canals that Leuckart (1853, *pl. 2, figs. 8, 9*; 1854, *p. 285, pl. 11, fig. 17*) described and illustrated.

The sex bells are essentially of the form shown by Vogt (1854, *pl. 19, figs. 1, 6*), made characteristically asymmetrical by the presence of one marginal wing-like expansion of the jelly, at the bell opening (Figs. 199, 200). None of the many examples, of both sexes, that I have examined among the *Albatross* material, now show the two longitudinal ribs described by Gegenbaur (1853). But in all of them the surface of the exumbrella has been more or less wrinkled by the preservation.

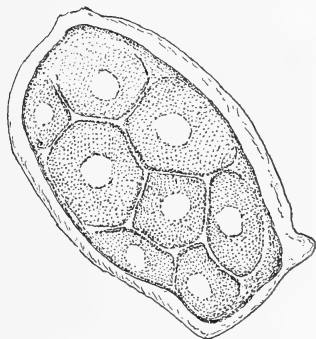


Fig. 200. *Galetta quadrivalvis*; female gonophore,  $\times 70$ .

Gegenbaur (1853), Vogt (1854) and Leuckart (1854) all describe the individual colonies (stems) as bearing gonophores of one sex only, and this is the view generally accepted. Neppi (1921), however, has reported an example in which the most distal gonophore was a male, the others female, suggesting that in reality this species is monoecious, and protandrous. I can throw no light on this point, for the segments of stem that I have been able to examine (in every case unisexual) were from an *Albatross* lot containing more than one example.

The gonophores bud off the pedicles of the siphons as Vogt (1854), Gegenbaur (1853), Leuckart (1853, 1854), and Schneider (1896) all found. Schneider's figure (1896, *pl. 45, fig. 37*) shows their relationship to the bract attachment and siphon, as well as the form of the latter so clearly that no further illustration is needed here. Vogt (1854, *pl. 19, fig. 3*) and more recently Schneider (1898, *pl. 12, fig. 31*) have already given satisfactory figures of the tentilla, which are of the ordinary Diphyid type.

*Galetta quadrivalvis* is widespread in the Eastern Tropical Pacific. The present locality-record is near Narborough Island of the Galapagos group. For

a summary of its known distribution in the Atlantic, Indo-Pacific and Mediterranean, see Moser, 1925, p. 141.

*Galettia quadridentata*, Quoy & Gaimard.

*Galeolaria quadridentata*, Quoy & Gaimard, 1834, p. 34, pl. 5, figs. 32, 33; Bigelow, 1918, p. 417, pl. 8, figs. 1, 2. (On synonymy, see p. 549 under *Galettia quadrivalvis*).

Station 29, 250-0 meters, two superior nectophores and ten inferior nectophores; fragmentary.

The superior nectophores listed above are identified by their basal sculpture; the loose inferiors, however, being identical in appearance with those of *Galettia*



Fig. 201. *Galettia quadridentata*; base of stem, found attached to inferior nectophore, with reserve-buds,  $\times 20$ ; from Arcturus Sta. 28.

*quadrivalvis*, might equally belong to that species. They are referred to *quadridentata* because taken in hauls which also yielded superior nectophores of that species, but none of *quadrivalvis*.

These nectophores are all more or less fragmentary: but the four basal teeth surrounding the oral opening of the superiors are conspicuous. And so far as can be seen in their present condition, they agree so closely with the *quadridentata* bells from the *Bache* collection (Bigelow 1918), that no further account is needed here.

The most interesting feature of the series is the fact that one of the inferior bells still had, attached, the basal part of the stem, and that the latter bore a

reserve bell well advanced in development, as well as the very young bud for a second (fig. 201). The larger of these buds already shows all essential features of a superior nectophore, including the four circumoral basal teeth, the divided ventro-basal lamella, and the characteristic lateral subumbrellal canals. The latter follow the same course as in *Galettia quadrivalvis* (c/f Fig. 195), and are similarly connected with the ventral canal by a transverse commissure. The smaller bud is still too young to show its future identity, whether as superior or as inferior nectophore. The situation of these reserve-bells relative to the stem in general, relative to the zone of proliferation for siphons, and relative

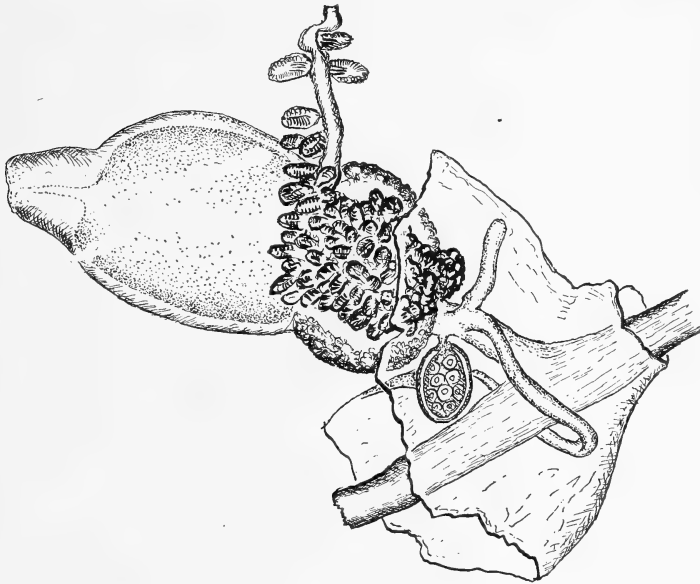


Fig. 202. *Galettia quadridentata*; portion of stem, with siphon, gonophore, and basal part of bract,  $\times 43$ ; from a specimen from Naples in the collection of the Museum of Comparative Zoology.

to the pedicles that bear the preexisting bells, is precisely the same as in *Galettia quadrivalvis* (Fig. 198).

*Galettia quadridentata* is apparently dioecious, for the present example bears only female gonophores as does another, better preserved, from Naples, in the collection of the Museum of Comparative Zoology. The arrangement of organs within each stem-group is likewise the same as in *G. quadrivalvis*, i. e. with the gonophores borne on the pedicles of the siphons, not on the stem proper (see Schneider 1896, pl. 45, fig. 37).

In the *Arcturus* specimens all the bracts have been lost. But in one from Naples, just mentioned (now in alcohol), these structures are intact on a considerable length of stem. And while they are so crumpled that it is not possible to reconstruct their natural outlines (further than that they are generally conical),

several clearly show the very stout canals (Fig. 202) mentioned by Leuckart (1854) and such as Schneider (1896, *pl.* 45, *fig.* 31) figured either for *G. quadridentata* or for *G. quadrivalvis* (p. 549). Occasional bracts are still in good enough condition to show that the attachment is by a muscular lamella, attached longitudinally along the pedicular attachment of the siphon (Fig. 203) proving that

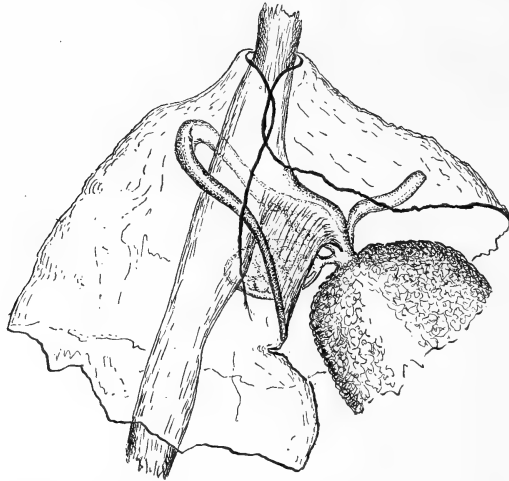


Fig. 203. *Galetta quadridentata*; another view of bract shown in Figure 202, to show its muscular attachment,  $\times 43$ .

this pedicle is morphologically a portion of the stem, as Leuckart (1854) long ago interpreted it, not of the siphon. The gonophore (this specimen is female) is attached just distal to the bracteal lamella (Fig. 202). One of the branches of the bracteal canal surrounds the stem, the other runs out roughly at right angles to the extension of the latter that bears gonophore and siphon (Figs. 202, 203).

This quadridentate form (whether distinct species or variety of *Galetta quadrivalvis*) has already been reported from the eastern side of the Pacific by Moser (1925, p. 140, Valparaiso, as "*Galeolaria quadrivalvis*"). Specimens of this type have also been definitely reported from the Mediterranean (Keferstein & Ehlers 1861, Bigelow 1918), and from the Indian Ocean (Quoy & Gaimard 1834). It seems that most of Moser's (1925) records for *G. quadrivalvis* also belong to *G. quadridentata*, hence the latter is evidently as wide-ranging (in fact cosmopolitan in warm seas) as is its bidentate relative.

*Galetta monoica*, Chun.

*Epibulia monoica*, Chun, 1888, p. 765 (1157).

For synonymy and descriptions, see Lens & Van Riemsdijk, 1908, p. 60, *pl.* 9, *figs.* 76, 77; Bigelow, 1911 a, p. 239, *pl.* 6, *figs.* 4-9; Moser, 1925, p. 144; Browne, 1926, p. 69.

Station 45, surface, two superior and one inferior nectophore.

Station 87, 1090-0 meters, one superior nectophore.

Station 94, surface, one inferior nectophore.

Although these bells are in a very fragmentary state, they all show the basal dentition so clearly that their specific identity is assured.

Moser (1925, p. 145) considers this form a "belanglose Varietät" of *G. quadrivalvis*. But as no intermediates, with regard to basal dentition, have been reported, though the typical *monoica* has been represented in several gatherings of siphonophores (most recently in Professor J. Stanley Gardiner's collection from the Indian Ocean described by Browne, 1926, and in the Madeiran collection reported upon by Candeis, 1929), it is more rational to regard it as a good species: as well-defined, indeed, as is any species of *Galetta*, and by alternative characters as precise.

The differences between *monoica*, *quadrivalvis* and *quadridentata*, may be summarized as follows:—

1. Superior nectophore: (A) with one dorsal and two dorso-lateral teeth; one lateral projecting lappet on each side, and divided basal-wing, *monoica*:—(B) with two dorsal teeth and divided wing, *quadrivalvis*:—(C) with four basal teeth (two dorsal, two lateral) and divided basal wing, *quadridentata*.

2. Inferior nectophore: (A) with three dorsal teeth, one lateral projecting angle on each side, and undivided baso-ventral wing, *monoica*:—(B) with four teeth (two dorsal, one lateral on each side), and with divided baso-ventral wing; *quadrivalvis* and *quadridentata*.

3. Outlines of inferior nectosac: simple in *monoica*; with anular contractions in *quadrivalvis* and *quadridentata*.

The superior bells of *monoica* so far examined also agree in a much shorter somatocyst than is usual either in *quadrivalvis* or *quadridentata*.

The present specimens are all so battered that they add nothing to the previous accounts. Additional information as to the stem-groups is especially to be desired.

Locality-records for *Galetta monoica* include the region of the Canaries (type locality), the general vicinity of the Cape Verdes and the triangle between Bermuda, the Bahamas and the coast of the United States in the Atlantic; the Eastern Tropical Pacific; Japanese waters; the Philippine and Malaysian regions; and the Tropical Indian Ocean. Evidently it is so widespread that it can be described as cosmopolitan in the warm belts of the oceans. It seems not to have been recorded as yet in the Mediterranean, but is to be expected there. The depths of capture prove it chiefly epiplanktonic.

*Galetta australis*, Quoy & Gaimard.

*Galeolaria australis*, Quoy & Gaimard, 1834, p. 42, pl. 5, figs. 29–31.

For synonymy, recent descriptions and discussions, see Bigelow, 1911 a, p. 238, pl. 5, figs. 8, 9 (omitting *G. chuni* from this synonymy); Moser, 1925, p. 145, pl. 4, figs. 1, 2; Browne, 1926, p. 57; Candeis, 1929.

Stations 94, 97, 98, 100, 102; hauls between surface and 300–0 meters; nine superior and eleven inferior nectophores.

The successive studies listed above have made this (next to *quadrivalvis*) the best-known *Galetta* so far as the conformation of the bases of the nectophores is concerned; the upper has a divided baso-ventral wing but no basal teeth; the lower also lacks basal teeth, and has an undivided ventro-basal wing.<sup>11</sup>

<sup>11</sup> Moser (1925, p. 148) states that I have shown the basal wing of the inferior nectophore as divided. Actually, as the legend states, the figure to which she refers (Bigelow, 1911 a, pl. 6, fig. 2), was of the superior nectophore, not the inferior.



In my earlier discussion I referred *Galetta chuni* Lens & Van Riemsdijk provisionally to the synonymy of *Galetta australis*. But Moser (1925) and Browne (1926) who have examined specimens of the *chuni* type, both consider it distinct, though on somewhat different grounds. According to the former the canal system is the most important distinction between the two (see her synopsis, p. 139), while differences in the length of the somatocyst are nothing more than variations. Browne, however, has reached the opposite conclusion from his observation that large specimens of this general group, whether with short somatocysts—(his "*australis*")—or long (his "*chuni*") invariably show the complex type of canalization, whereas small ones vary in this respect, indicating that the oblique commissures connecting the ventral canal with the laterals are usually formed late in development. And my own observations tend to corroborate this, four of the superior nectophores in the *Arcturus* series clearly showing this oblique commissure-canal, whereas one small one (about 7 mm. high) as clearly lacks it. Similarly, 35 specimens more than 10 mm. long from the Eastern Tropical Pacific all show the commissure; also 10 examples (v 10 mm. long) from the Western Atlantic (*Bache*), 10 from Japanese waters (*Albatross*) and 20 taken among the Philippines.

I must point out that my earlier illustration (1911 a, pl. 6, fig. 3) does not correctly show the canalization of the inferior nectophore, the connection of the lateral canal with the pedicular having been omitted. This is correctly shown by Moser (1925, pl. 3, fig. 2) as looped, just as it is in *Galetta quadrivalvis* and in *Galetta monoica*.

Final decision as to whether the length of the somatocyst is any more significant as a specific character, as between *australis* and *chuni*, can only come from cumulative evidence. In the eight superior nectophores of the present series, the somatocyst falls considerably short of the mid-level of the nectosac i. e. is of small *australis* type; this also applies to the series collected by the *Albatross* in Philippine waters (Bigelow, 1919, p. 337). Ten *Albatross* specimens from Japan likewise all have very short somatocysts; so, too, 35 from the Eastern Tropical Pacific; and 10 collected by the *Bach* in the Western Atlantic. This, then, seems a comparatively constant character. And when given specimens can almost always be referred definitely to the one group or to the other, such groups can fairly be dignified with the name of "species," in the sense in which this term is necessarily employed among siphonophores, even should an occasional intermediate be found.

Candeis' (1929) discovery of superior nectophores resembling those of the well-known *Galetta australis* in the conformation of the base, but with extremely minute somatocyst, raises, afresh, the question of the relationship to *australis* of the form described by Gegenbaur (1854, "*Diphye turgida*") as lacking that organ. Here the *Arcturus* series gives no help.

The inferior nectophore of *Galetta australis* (the identity established by the fact that the Eastern Pacific collection of the *Albatross* contained several pairs, still connected)<sup>12</sup> bears a very long undivided baso-ventral wing, but (like the

<sup>12</sup> Moser (1925, p. 148) seems to have overlooked this observation, for she states that such inferior bells "muss anderswohin gehören, da auch ihre Lateralkanten sehr kurtz statt lang sind."

superior nectophore) lacks basal teeth. Moser points out that the lateral ridges of the inferior nectophores in the *Gauss* series that were taken with superior nectophores of *australis* (but not actually connected), extend down to the level of the bell opening, instead of ending an appreciable distance above the latter as they are shown in a photograph of one of the *Albatross* specimens (Bigelow, 1911 a, pl. 5, fig. 9) and as they appear in another from that same series, with two bells still connected, now in the collection of the Museum of Comparative Zoölogy. But as Browne (1926, p. 69) has remarked, "to see clearly these ridges it is necessary to have very good specimens."

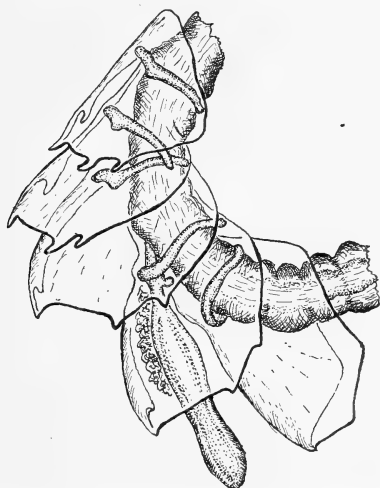


Fig. 204. *Galetta australis*; portion of stem, to show bracts,  $\times 27$ ; from a specimen from Albatross Sta. 4661.

The early accounts of the stem-groups (Sars, 1846, "*Diphyes biloba*"; Gegenbaur 1860, "*Diphyes sarsii*"), show that they closely resemble those of *G. quadrivalvis* in the conical shape of the bracts, in the small size of the gonophores, and in the lack of special swimming bells. According to Gegenbaur, the bract has one prominent marginal tooth or angle; whereas Sars credits it with four. But portions of stems, with the bracts still attached, from the *Albatross* Eastern Pacific series, suggest that this difference is chiefly one of the stage of development and state of preservation, for younger bracts show four strong marginal teeth, which are represented only by angles in older bracts. One segment of stem, in particular, shows this succession very clearly (Fig. 204).

The very stout bracteal canals recall those of *Galetta quadrivalvis*, by their prominence. And the gonophores, siphons and tentacles are similarly borne on tubular, cylindrical diverticula from the stem, which at the same time form pedicles for the siphons (Fig. 205). Here (as in *quadrivalvis*) one gonophore per stem-group seems to be the invariable rule.

In each of the specimens collected by the *Albatross* in the Eastern Tropical and in the Northwestern Pacific, with base of stem intact, a bud is to be seen

for a future nectophore (Figs. 206–207).<sup>13</sup> In most cases it may be assumed that this, bud is fated to develop into an inferior nectophore, because it is a large superior nectophore that still bears the stem. But in one case it is a large inferior nectophore, that bears the base of the stem, and here one of the two reserve buds (Fig. 207) evidently represents a future superior bell, just as is the case with one of *Galetta quadridentata* shown in figure 201 (see also p. 557). This

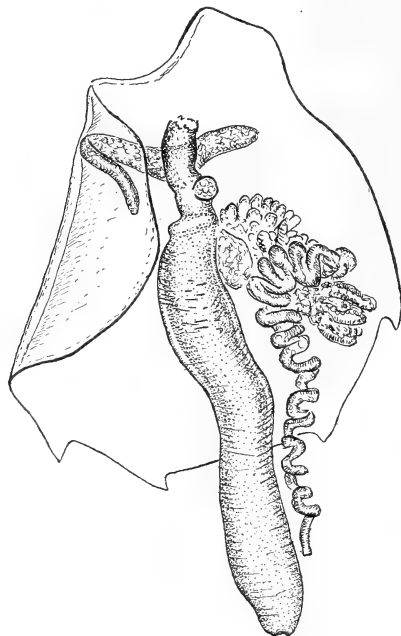


Fig. 205. *Galetta australis*; group of appendages,  $\times 50$ ; from a specimen from Albatross Sta. 4727.

raises the interesting question whether the future fate of such buds (i. e., to form superior or inferior bells) is determined from their first appearance, or whether it depends upon which of the two bells has become detached from the stem.

As more than two large bells have never been seen in any specimen of *Galetta*, we have as yet no knowledge of how many may be formed in succession: nor do we know whether the successive detachment and subsequent replacement by younger bells is a normal process, or whether it is simply a method of repairing accidental mutilation. But in view of the facts that the process has now been demonstrated in three species of the genus (*quadrivalvis*, *quadridentata* and *australis*), and that reserve buds have been found in most (if not all) of the specimens with stem attached on which they have been sought, the former alternative seems the more likely.

<sup>13</sup> None of the *Arcturus* specimens show this, having lost all trace of stems.

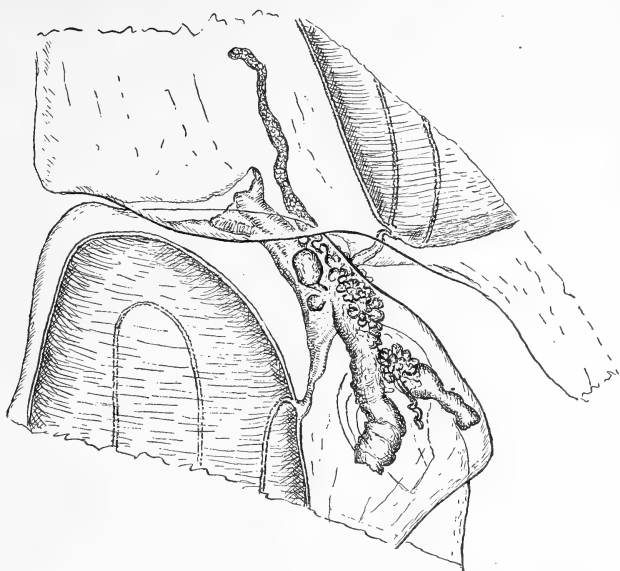


Fig. 206. *Galetta australis*; base of superior, and apex of inferior nectophore, to show their attachment, and the reserve-buds; from a specimen from Albatross Sta. 4704.

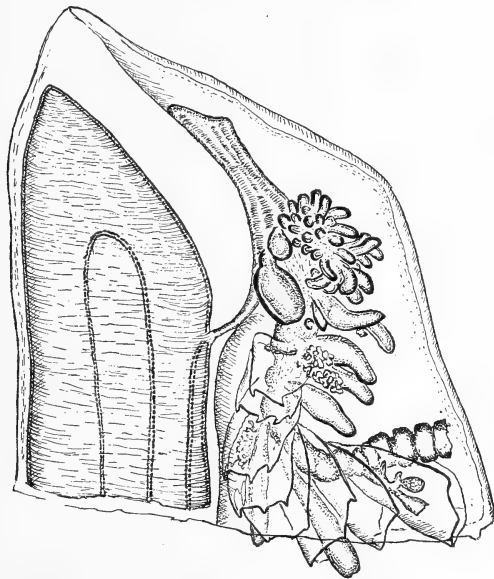


Fig. 207. *Galetta australis*; apex of inferior nectophore,  $\times 15$ ; to show base of stem, and reserve-buds; from Albatross Sta. 2747.

From the systematic standpoint, the fact that the occurrence of this succession of bells characterizes a group of species is of much interest, for it sets this category apart from the Diphyinae much more sharply, and in a more significant way, than do such morphological features as depth of the hydroecial indentation in the base of the superior nectophore, or the prominence of the ridges on the surface of the latter.

The *Arcturus* captures of *Galettia australis* (all from the general vicinity of Bermuda, in the Atlantic) call for no special comment, for this species is now known to be widespread in all oceans (identity of the Atlantic *biloba* with the Indo-Pacific *australis* having been sufficiently established by comparison between series from the different oceans). It has already been taken at many stations between Bermuda, Bahamas, and Chesapeake Bay by the *Bache*. It is rather surprising, however, that none of the many tows that the *Arcturus* made in the Panama-Galapagos region yielded it, for the *Albatross* had it at a number of stations in this part of the Pacific (Bigelow, 1911 a, p. 238).

*Diphyes dispar*, Chamisso & Eysenhardt.

*Diphyes dispar*, Chamisso & Eysenhardt, 1821, p. 365, pl. 33, fig. 4.  
For synonymy, see Bigelow, 1911 b, p. 257; Moser, 1925, p. 170; Browne, 1926, p. 79.

Stations 3, 11, 47, 69, 98, 102; hauls between the surface and 300-0 meters; two pairs of nectophores still united, with part of stem intact; also, nine loose superior and two loose inferior nectophores.

This well-known species has often been described and figured; its superior nectophore is so characteristic in appearance that it is one of the most easily recognized of siphonophores. The present series, all more or less fragmentary, add nothing to previous accounts of better material: see especially Haeckel, (1888 a, p. 153, pl. 33, 34, "*D. compressa*"), and Moser, (1925, p. 185, pl. 5-7, pl. 8, figs. 1, 2) who has given a summary of the characters that separate it from *D. bojani*.

Like so many siphonophores, *D. dispar* is now known to be cosmopolitan in tropical and warm temperature latitudes, except that it has not been found in the Mediterranean, a curious fact to which Moser (1925, p. 180) has already called attention. It had already been reported from the general regions, Atlantic and Pacific, covered by the *Arcturus* cruise.

*Diphyes appendiculata*, Eschscholtz.

*Diphyes appendiculata*, Eschscholtz, 1829, p. 138, pl. 12, fig. 7.  
For synonymy, see Bigelow, 1911 a, p. 248; Moser, 1925, p. 231 (as "*Diphyes sieboldii*," K  lliker), Browne, 1926, p. 71).

Moser (1925) has revived K  lliker's (1852) name *sieboldii* for this cosmopolitan and well-known species, on the ground that Eschscholtz' (1829) description might apply equally to any one of three species of the genus. Even were that the case, stability of nomenclature would be served, and the generally accepted rules best adhered to by following the lead of the several reviewers who have used the name *appendiculata* for the Diphyid in question, which otherwise will always remain a stumbling block. And the original description does sufficiently warrant this course, for Eschscholtz' account and illustration mention features making it practically certain that his *appendiculata* was the

same species that has subsequently been so often reported as *D. bipartita* Costa or as *D. sieboldii* Kölliker.

Thus he states (p. 139) that in neither nectophore does the opening bear teeth (clearly this refers to the dorsal and lateral teeth of the nectosac, not to the dorsal hydroecial wall). His description (p. 138) of the superior nectophore as showing only two angles on the side occupied by the nectosac, but three angles on the side occupied by the hydroecium, is a clear statement of the suppression of the dorsal ridge of the species in question—meaningless if applied to any other Diphyid yet known. Lastly his illustration of the superior nectophore shows the outline of the hydroecium, as well as the relative proportions of nectosac and somatocyst, a combination of characters sufficient for identification in this case.

Few, in fact, of the early accounts or illustrations of the bells of siphonophores, prior to the middle of the nineteenth century, are more diagnostic than Eschscholtz' of *appendiculata*.

*D. appendiculata* was taken at Stations 11, 84, 87, 97, 98 and 100, in hauls between the surface and 1000–0 meters. The material consists of about 75 superior and three inferior nectophores. This species is now so well known morphologically that the present series calls for no special comment. It affords cumulative evidence that the left lateral ridge invariably rises some distance below the apex in the superior nectophore; no variant from this state has yet been recorded. Examination of Atlantic and Pacific Diphyids of this type have shown that they are indistinguishable.

Because of their transparency, the inferior nectophores are apt to be overlooked among the other plankton; probably the poverty of their representation in the *Arcturus* material is so to be explained.

*D. appendiculata* has already been reported on various occasions from the parts of the Pacific and Atlantic oceans sampled by the *Arcturus* hauls.

*Diphyes bojani*, Eschscholtz.

*Eudoxia bojani*, Eschscholtz, 1825, p. 43, pl. 5, fig. 13.

For synonymy and description, see Bigelow, 1911 a, p. 251, pl. 7, figs. 2, 3; pl. 8, fig. 6; pl. 9, figs. 1, 2; pl. 10, figs. 2, 3; pl. 11, fig. 5; pl. 12, fig. 1; 1918, p. 424; 1919, p. 340; Moser, 1925, p. 208, pl. 13; fig. 1; Browne, 1926, p. 80.

Stations 2, 11, 87, 97, 102; hauls between the surface and 1500–0 meters; four pairs of nectophores still united, about 80 loose superior and two loose inferior nectophores, also nine superior and one inferior nectophores labelled simply "Atlantic."

The morphology of this species has been described and figured in such detail in the publications quoted above, that it is now one of the best-known of Diphyids. And the fact that its representatives in the Atlantic and in the Pacific are specifically indistinguishable has been sufficiently established by actual comparison of series from the two oceans.

As Moser (1925) has shown, the one diagnostic feature than can be relied upon to separate the superior nectophore of *D. bojani* from that of *D. dispar* at all stages in development, is the presence in the former of a crest on the dorsal wall of the hydroecium below the level of the nectosac. Usually this crest or ridge bears from one to three or four teeth, but Browne (1926) records specimens in which these teeth were lacking.

The details of origin of the ridges at the apex of the superior nectophore, and the degree to which the lateral ridge are expanded, wing-like, shows much individual variation. It is therefore worth noting that the great majority of the present series, both from the Atlantic and from the Pacific show wing-like expansions of considerable breadth (c/f Bigelow, 1911 a, *pl. 8, fig. 6*) and have five ridges at the apex.

*D. bojani* is cosmopolitan in tropical and subtropical seas, already recorded in the general regions (Atlantic as well as Pacific) covered by the *Arcturus* records. For a survey of its distribution as now known, see Moser, 1925, *p. 211*, to whose summary the Philippine waters must be added (Bigelow 1919, *p. 3*). The depths of capture of the various series so far reported show that *bojani* inhabits chiefly the upper stratum of water.

*Diphyes mitra*, Huxley.

*Diphyes mitra*, Huxley, 1859, *p. 6, pl. 1, fig. 4*.

For synonymy, see Moser, 1925, *p. 256*; for description, Bigelow, 1911 a, *p. 258, pl. 7, fig. 9; pl. 9, fig. 4; pl. 10, figs. 4, 5; pl. 11, fig. 6; pl. 12, fig. 5; Moser, 1925, p. 260, pl. 8, figs. 6-8; pl. 13, figs. 8-11; pl. 14; Browne, 1926, p. 73*.

Stations 45, 69, 74, 98; hauls between the surface and 1500-0 meters; six superior and one inferior nectophores.

These few loose nectophores add nothing to the detailed studies of this species that have recently been made (see above).

*D. mitra* was already known to be widespread in the tropical and warm temperate belts of all the oceans. Having been reported at many localities in the Eastern Tropical Pacific, it was to be expected at the *Arcturus* stations there. For the most recent geographic summary, see Moser, 1925, *p. 258*.

*Chuniphyes multidentata*, Lens & Van Riemsdijk.

*Chuniphyes multidentata*, Lens & Van Riemsdijk, 1908, *p. 13, pl. 1, figs. 9-11, pl. 2, figs. 12-15; Bigelow, 1911, p. 348; 1911 a, p. 262, pl. 8, fig. 9; pl. 10, fig. 7; pl. 12, fig. 6; 1913, p. 73; 1918, p. 425; 1919, p. 344; Moser, 1925, p. 357, pl. 23, figs. 1-4, pl. 24, figs. 1, 2*.

Station 10, 909-0 meters, one superior nectophore.

Although the single nectophore (about 30 mm. long), is much crumpled, the bells of this species are so characteristic in appearance that identification is positive.

This species has been described fully, in the accounts of the *Albatross*—Eastern Pacific, Biscayan and *Gauss* collections, quoted above. The only morphological feature calling for comment here is the arrangement of the ridges, and the conformation of the base of the superior nectophore. All specimens so far examined have shown four such ridges, dorsal, ventral, and a lateral on each side, meeting, quadrate, at the apex: apparently there is no variation in this respect. The dorsal and ventral ridges divide, dichotomously, a short distance below the apex (for lateral views, see Bigelow, 1911 a, *pl. 8, fig. 9*, and Moser, 1925, *pl. 23, fig. 1*). The ventral ridge runs, undivided, along about one-third the length of the nectophore (Fig. 208). There, according to my earlier account, it meets the opening of the hydroecium, (1911 a, *p. 262*), whereas Moser (1925, *p. 358*), describes it as dividing to continue as "Paarigen Ventralkanten flügelartig verbreitert im Bogen zur Basis, das offene Hydrocium zwischen sich fasend . . .". Correspondingly, I have interpreted the

base of the whole marginal sector, extending antapically from the beginning of the hydroecial groove, as belonging to the "base," whereas Moser uses the latter term in a more restricted sense.

The difference, however, is merely one of interpretation and of descriptive wording, not of observation nor of fact. All specimens so far examined show a well-defined groove, commencing at the point where the ventral ridge either

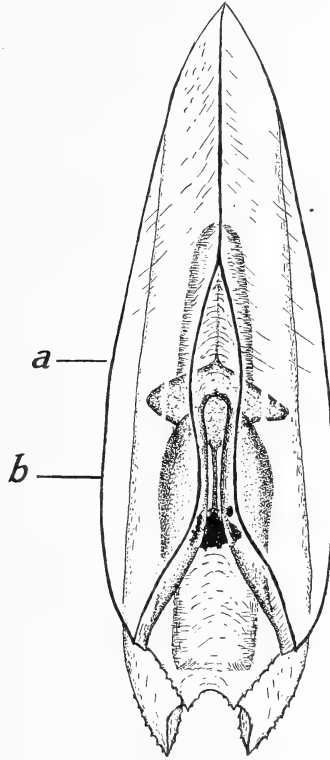


Fig. 208. *Chuniphyes multidentata*; ventral view of superior nectophore,  $\times 7$ ; from Albatross Sta. 4759.

divides (according to the interpretation) or merges into the two hydroecial walls. Proceeding antapically, this groove widens and deepens; at about the mid-level of the bell, and about opposite the mid-level of the somatocyst, it abruptly deepens, merging into a deep and voluminous hydroecial cavity.

Cross-sections of the bell at successive levels thus have the outlines shown in figure 209. A comparison with Moser's illustration (1925, *pl.* 23, *fig.* 2) will bring out the correspondence in this respect between Pacific and Atlantic specimens.

The leaf-like marginal extensions of the left and right hydroecial wings,



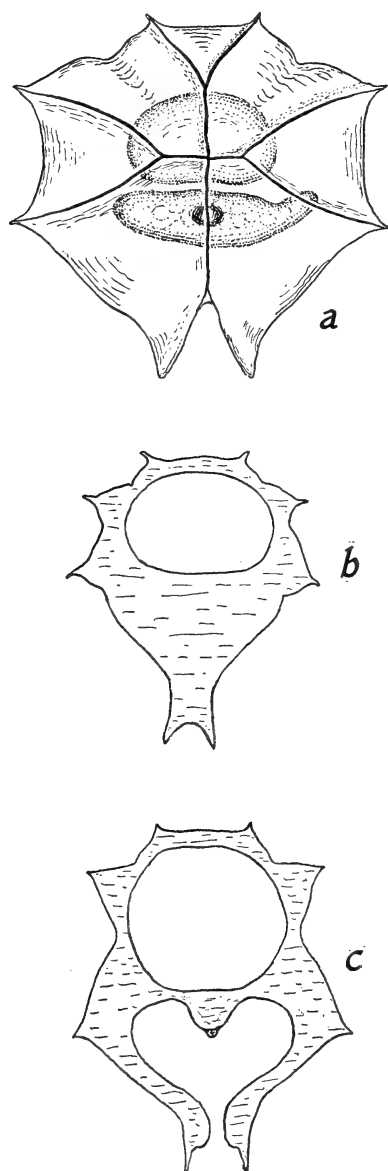


Fig. 209. *Chuniphyes multidentata*; superior nectophore; apical view (A), and cross sections (B & C) at the levels marked A and B on Figure 208; from Albatross Sta. 4759.

regarded by Moser as continuations of the ventral ridge, continue around the margin, being joined by the ventro-lateral ridges, until finally they merge into the dorso-basal margin of the hydroecium. Thus, whether the bell is to be described as having seven ridges at the base, or only six, depends on just where, along the ventro-basal margin, the "base" is interpreted as commencing.

As appears in side view, the base shows the following definite projecting angles: one, (smaller) at the termination of each dorsal ridge; one (larger) at the termination of each dorso-lateral ridge; and one (less prominent) on each side at the point where the margin of the dorsal wall of the hydroecium joins each of the lateral wings that enclose the latter. There are no marginal teeth or projecting angles at the termination of the ventro-lateral ridges. These six basal angles or teeth are more or less prominent, according to the state of contraction or flaccidity of the bell as a whole.

According to Moser (1925, p. 360), adult nectophores show no denticulation on ridges or on basal margin, though young bells are always to some extent serrate. Preserved specimens vary in this respect. Thus in one of the *Albatross* specimens from the Eastern Tropical Pacific (Bigelow, 1911 a, *pl.* 8, *fig.* 9), the lateral and dorsal ridges and the basal margin were weakly denticulate. And a strongly contracted and well preserved specimen from Alaskan waters (Fig. 208) shows much this same condition, with the dorsal margin of the hydroecium, the lateral and dorsal margins of the bell opening, and the basal parts of the dorsal and dorso-lateral ridges all weakly and irregular serrate. A Philippine specimen bears very small and sparse denticulations along the margin, but no trace of serration on the ridges: one bell from the Bay of Biscay shows much this same state, but in others from the same collection margin and ridges are perfectly smooth.

In the *Arcturus* example the somatocyst has been destroyed; but remaining indications of its outline show that its median dilation had an ovate outline, longer in the transverse than in the longitudinal axis, thus falling well within the range of variation previously recorded.

All records for this species have been from tows from considerable depths; clearly it is bathypelagic in habit. And like so many other members of this faunal community, it is widespread in all the great oceans. Although so far reported from only seven collections, the records include Malaysian and Philippine waters; Eastern Tropical and Northwestern Pacific; Eastern Sea between China and Japan; the Bay of Biscay and the mid-Atlantic between 28° N. and 32° S.

#### Family UNCERTAIN.

#### Genus *Archisoma*, Bigelow 1911.

*Archisoma natans*, Bigelow.

*Archisoma natans*, Bigelow, 1911 a, p. 266, *pl.* 20, *fig.* 6; 1919, p. 344; Moser, 1925, p. 383.

Station 61, 909-0 meters, one specimen; bract 54 mm. long and swimming bell 31 mm. long.

Only two specimens of this remarkable eudoxid, of problematical parentage, had previously been taken, both of them by the *Albatross*, the first in the Eastern

Tropical Pacific, the second in the Gulf of Boni, Celebes. This third example is therefore a welcome find.

The general characteristics of *Archisoma* have already been described (see above): the present specimen, however, shows some minor divergences that deserve notice, though their systematic significance cannot be determined until larger series are studied. As has already been pointed out in earlier accounts,

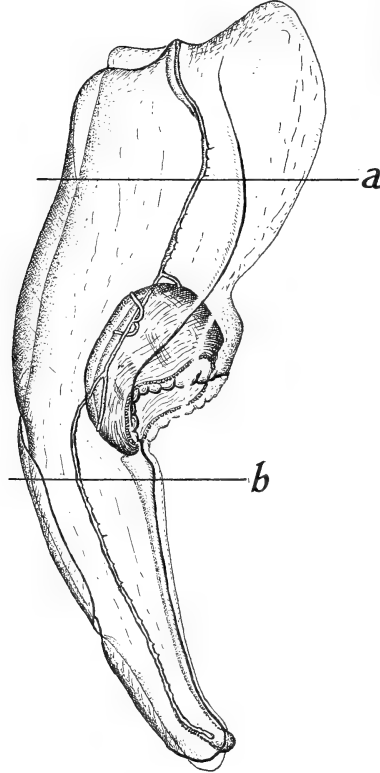


Fig. 210. *Archisoma natans*; lateral view of special nectophore,  $\times$  about 3; from *Arcturus* Sta. 61.

both special nectophore and bract are highly characteristic in conformation; the excellent example of the former in the *Arcturus* collection makes its illustration (Figs. 210–216) desirable.

I must add to the earlier account, that the ventral-lateral faces of the nectophore are expanded in two wings. In their present state, these overlap, (right and left wings alternately) as shown in figure 210 so as to form an enclosed hydroecial tube extending from end to end of the bell.

The ventral face of the nectosac is also deeply indented along the longitudinal axis of the bell, a feature that seems characteristic, not the result of

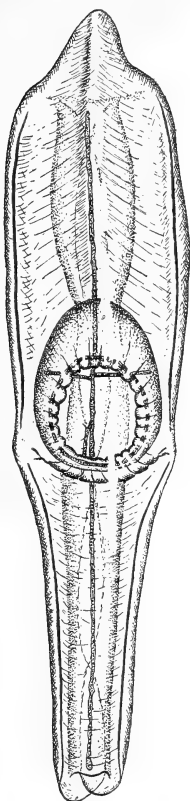


Fig. 211. *Archisoma natans*; dorsal view of nectophore illustrated in Figure 210,  $\times$  about 3.

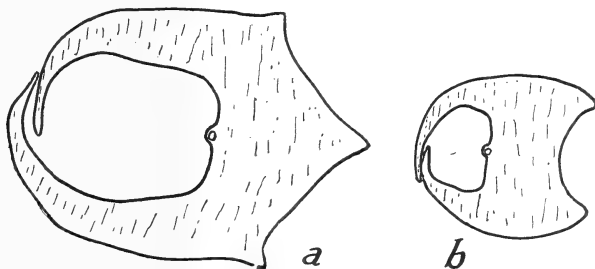


Fig. 212. *Archisoma natans*; schematic cross sections of the nectophore,  $\times$  4.7, at the levels indicated on Figure 210.

contraction since this was also true of the type specimen (Bigelow, 1911 a, *pl.* 20, Fig. 6). The arrangement of the canals of the nectophore is precisely as in

the Celebes specimen (Bigelow, 1919, p. 345); i. e. there is one main trunk running lengthwise along the dorsal side of the hydroecium from the point of

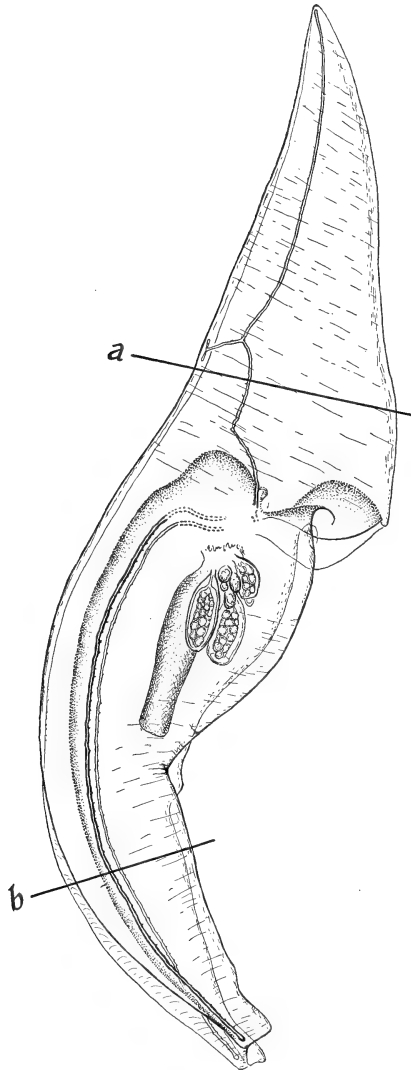


Fig. 213. *Archisoma natans*; lateral view of bract,  $\times$  about 2.5, of specimen illustrated in Figure 210.

pedicular attachment at the superior end of the bell. This trunk gives off one short branch running to the superior face of the nectosac, another to the inferior

face of the latter, and a pair of branches (arising in union), running to the ventral face of the nectosac, slightly above its mid-level. In the nectophore of the type specimen the main trunk gives off a short transverse branch, dorsad,

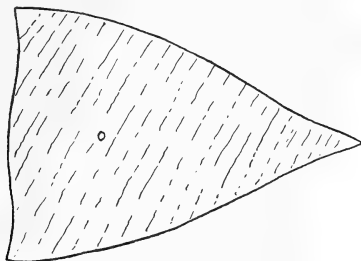


Fig. 214. *Archisoma natans*; schematic cross section of the bract,  $\times 4.5$ , at the level marked A on Figure 213.

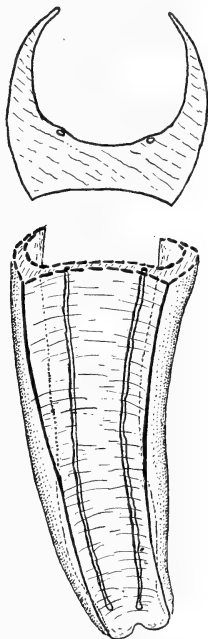


Fig. 215. *Archisoma natans*; dorsal view of inferior portion of bract,  $\times 4.5$ , with schematic cross-section at the level marked B on Figure 213.

slightly below the level of the nectosac. In the present example this branch is lacking, but the wall of the main trunk shows various minor irregularities.

The dorsal surface of the inferior gelatinous prolongation of the nectophore is definitely concave (not mentioned in the earlier accounts) with each of its

dorso-lateral angles extending upward, toward the apex, across the dorso-lateral face of the superior half of the bell, as a fairly distinct ridge. These ridges did not appear on the type—but the latter was not in such good condition. The schematic cross-sections (Fig. 212) illustrate the resultant contour.

The canalization of the bract (Fig. 213) differs in one interesting respect from that of the two examples previously described. In both of these the two descending hydroecial trunks arise together, but at once separate; and by re-examination, I have verified my account of them as “descending over the two

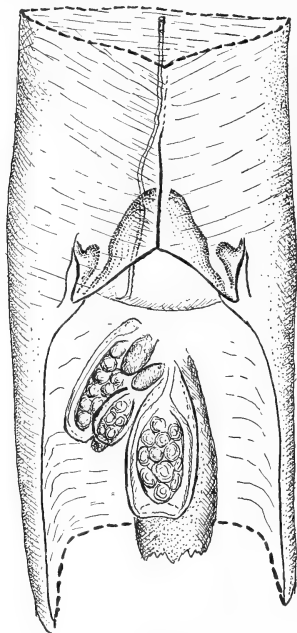


Fig. 216. *Archisoma natans*; ventral view of mid-sector of bract,  $\times 4.5$ , illustrated in Figure 213.

faces of the hydroecium, on the right and left respectively to unite near the tip of the bract” (1919, p. 345), beyond which a single trunk extends a short distance further. In the present example the trunks arise similarly, and follow in general a similar course down the hydroecium, but instead of uniting, they continue independent to the tip of the bract, where each terminates in a small dilation (Fig. 213). The ascending trunk has a transverse branch running to the dorsal surface as in the Celebes specimen (in the type this part was damaged).

In its general form the bract resembles that of the original specimen (Bigelow, 1911 a, pl. 20, fig. 61), but is more strongly pyramidal above the level of the hydroecium; triangular in cross-section (Fig. 214); its angles are sharper; its dorsal surface (rounded in the *Albatross* specimen) is concave below the mid-level of the bract, with concavity increasing toward its inferior tip (Fig. 215).

The apex of the hydroecial cavity of the bract also shows a peculiarly complex conformation, with secondary recesses (Fig. 216), that were not seen in the type, though in this case preservation may have been responsible for the apparent difference. Finally, in the present example the hydroecial furrow extends inferiorly right to the extremity of the bract (Fig. 213), as was also true of the Celebes specimen,<sup>14</sup> whereas in the type it terminates some distance above the tip.<sup>14</sup>

In the *Arcturus* specimen the region of attachment for siphon and pedicular canal has been destroyed, as has the tentacle. But three well developed gonophores containing large eggs are still intact, with young buds for several more (Fig. 216). Evidently *Archisoma* is dioecious.

The significance of the small differences between the three specimens of *Archisoma*, that have so far been seen, is bound up with the problem of the parentage of this peculiar eudoxid.

In my discussion of the Celebes example I pointed out that the canals of the nectosac were of a type peculiar (so far as known) to the Monophiid *Nectopyramis thetis* (Bigelow, 1911), suggesting identity with that species, rather than with some Prayid as I had previously (1911 a) suggested. Moser (1925), however, thinks it likely that *Archisoma* is the eudoxid of *Praya dubia*.

This point can not be settled until the stem-groups of *Praya dubia* and of *Nectopyramis thetis* have been studied. It is clear, however, that if *Archisoma* is the eudoxid of a *Nectopyramis*, it belongs either to *N. thetis* or to some species as yet undescribed, because the eudoxid of *N. diomedae* not only has a bract very different in form, but lacks the special nectophore (Bigelow 1911 a, pl. 1). If, however, *Archisoma* belongs to *Praya*, *P. dubia* is the probable parent as Moser believes, because (if my identification of the stem-groups described above is correct), *P. reticulata* lacks a special nectophore, and has a very different bract.

#### Family AGALMIDAE, Brandt 1835

*Agalma okeni*, Eschscholtz.

*Agalma okeni* Eschscholtz, 1825, p. 744, pl. 5, fig. 17; 1829, p. 151, pl. 12, figs. 1 a-1 d.

For synonymy and detailed descriptions see Bigelow 1911 a, p. 277, pl. 17.

This species was taken at Stations 26, 28, 38, 39, 45, 51, 52, 56, 57, 62, 74, 78 and 107, in hauls ranging in depth from surface to 1274-0 meters. This material consists of parts of upwards of 18 colonies, plus a large number of detached nectophores and bracts. None of the specimens are as well preserved as might be wished. But fortunately the species is made so easily recognizable by the characteristic outline and unusually firm texture of swimming bells and bracts, as well as by the relatively stiff, short stem, that identification is positive.

Kawamura (1911) has recently reopened the question as to the relationship of the *A. polygonata* of Dana (1858) to *A. okeni*, with which most recent authors have united it; unfortunately I have not been able to consult this paper. All the present series and most of the other specimens that I have seen (1911 a, pl. 17, fig. 12) show the conformation of the nectophores pictured by Dana (1858), in which each lateral face is transversely divided by two ridges, so that each

<sup>14</sup> These have been re-examined.



side of the bell may be described as consisting of three facets. Eschscholtz' (1829) figures of the swimming bells of his *A. okeni* are so generalized that they are not diagnostic in this respect, for they do not show the transverse ridges at all. So far as they go, however, they are more compatible with the presence of only one of the ridges in question rather than with two on each lateral face of the nectophore. Among the collection of *Agalma* of this general type in the Museum of Comparative Zoölogy, there are a few specimens in which the bells (in the preserved state) show only one transverse ridge on each lateral face. These specimens, however, are all in a very flaccid condition, while the prominence of the ridge in question varies considerably in the specimens with show two. Furthermore, while Haeckel's (1869, *pl.* 10, *fig.* 67) figure of the nectophores of his *Crystallodes rigidum* show only one ridge, his pictures of *C. vitrea* (1888 a, *pl.* 17, *fig.* 10). Here there can be no question of a specific difference, because one of the *Arcturus* series (station 74, good condition) has bracts of both these types still attached to the one siphonsome.

And this explanation is rendered the more likely by the fact that bracts also show an interesting variation, some of them having only the four chief marginal facets, while in others there are one or two subsidiary facets in addition (1911 a, *pl.* 17, *fig.* 10). Here there can be no question of a specific difference, because one of the *Arcturus* series (station 74, good condition) has bracts of both these types still attached to the one siphonsome.

In short, there seems no justification for reviving the name *polygonata* as distinct from *okeni*.

This species of *Agalma* was already known to be widespread, and general in its occurrence in the warm belts of all oceans including the Mediterranean, as recently found by Moser (1925).

#### Family AGALMIDAE, genus and species?

Bracts, nectophores and fragments of stem of agalmids, too fragmentary for identification, were also taken at Stations 32, 38, 39, 51, 112, 113.

#### Family FORSKALIIDAE, Haeckel, 1888.

##### *Forskalea* species?

One stem, denuded of all appendages except a few young nectophores, is referred to *Forskalea* because these show traces of the pedicles characteristic of this genus.

Station 59, 1090-0 meters.

#### Family PHYSOPHORIDAE, Eschscholtz 1829 (sensu Huxley 1859).

##### *Physophora hydrostatica*, Forskål.

*Physophora hydrostatica*, Forskål, 1775, *p.* 114, 1776, *tab.* 33, *fig.* e.  
For synonymy, see Bigelow, 1911 a, *p.* 293.

This well known species was represented at Stations 29, 59, and 74; in hauls between the surface and 909-0 meters, a total of 17 specimens, most of them in very fragmentary condition.

*Physophora hydrostatica*, thanks to the simplicity of its architecture, and

to the fact that it preserves well, even in alcohol, is the best known of the Physophorae. At the same time it is the most easily recognized in its group. The present fragmentary material adds nothing to the previous accounts.<sup>15</sup>

Brandt (1835) long ago recorded *Ph. hydrostatica* (as "*Ph. ambigua*") from the Eastern Tropical Pacific. The *Albatross* had it at several stations in the same general region of the Pacific as the *Arcturus*—also in the Sulu Sea; while Huxley (1859) records it from the southern part of the Indian Ocean, and Lens & Van Riemsdijk (1908) from Malaysia. Evidently it is as widely distributed in the Indo-Pacific as it is in the Atlantic and Mediterranean. So far as I am aware, however, it has not yet been recorded from as high latitudes in the Pacific as in the Atlantic where it appears not infrequently in the Norwegian Sea around Iceland and right up to the Arctic Circle (Paulsen 1909, Romer, 1902).

#### Family ANTHOPHYSIDAE Brandt 1835.

*Anthophysa rosea*, Brandt.

*Anthophysa rosea*, Brandt, 1835, p. 35; Bigelow, 1911 a, p. 296, pl. 20, figs. 7-13; pl. 21, figs. 1-5; pl. 23, figs. 1-5; Moser, 1925, p. 441; Browne, 1926, p. 83.

Probably also identical is the Atlantic species with the following synonymy.

*Athorybia formosa*, Fewkes, 1882, p. 271-275, pl. 5, figs. 3, 4; pl. 6, figs. 7-14; Schneider, 1898, p. 162.

*Plocophysa agassizii*, Fewkes, 1888, p. 318, pl. 17, figs. 1, 2.

*Diploxybia (formosa)*, Fewkes, 1888, p. 320, Footnote.

*Anthophysa formosa*, Haeckel, 1888, p. 43, 1888 a, p. 276; Chun 1897, p. 61, pl. 3, figs. 7, 8; Bedot 1904, p. 5, pl. 1, figs. 4-15.

*Anthophysa darwini*, Haeckel, 1888, p. 43, 1888 a, p. 278, pl. 12, figs. 7-9.

?*Angela cytherea* Lesson, 1843, p. 496, pl. 9, fig. 1.

Station 26, surface, two specimens, without bracts but otherwise in excellent condition.

Station 107, offing of Cape Hatteras, 1454-0 meters, one very fragmentary specimen.

The two Pacific specimens (station 26) agree so closely with the *Albatross* specimens from the same general region (Bigelow 1911 a) that no account of them is called for. Beyond the fact that the Atlantic specimen is a typical *Anthophysa*, little can be made out of it, for not only have all the bracts and siphons, and most of the palpons been detached, but the corm is so much damaged that the position of the siphons cannot be seen. That it is so fragmentary is much to be regretted, for no one has yet been able definitely to settle the relationship of the Atlantic to the Pacific representative of *Anthophysa* by actually comparing material from the two oceans. The most that can be said of this Atlantic example is that the peculiar cap-like arrangement of the bractal lamellae, partially surrounding the pneumatophore, agrees with the Pacific specimens. But this agreement has perhaps little bearing on the specific relationship, being common to the genus; specific characters are rather to be looked for on bracts, etc.

<sup>15</sup> See especially Sars 1877, Chun, 1897; for development, Haeckel, 1869 ("*Physophora magnifica*"). The Report on the Albatross Eastern Pacific Collection (Bigelow, 1911 a, pl. 16, contains a series of photographs.

*Athorybia rosacea*, Forskål.

*Physophora rosacea*, Forskål, 1775, p. 120; 1776, pl. 43, fig. B.  
For synonymy, see Bigelow, 1911 a, p. 349.

This species was represented at Stations 29, 53, 54, 59 and 74, in hauls varying in depth from 272-0 meters to 2000-0 meters. The material consists of seven fragmentary corms only two of which (stations 53 and 74) still bear any of the appendages, and 30 loose bracts.

Although *Athorybia* was one of the earliest studied of siphonophores (recog-

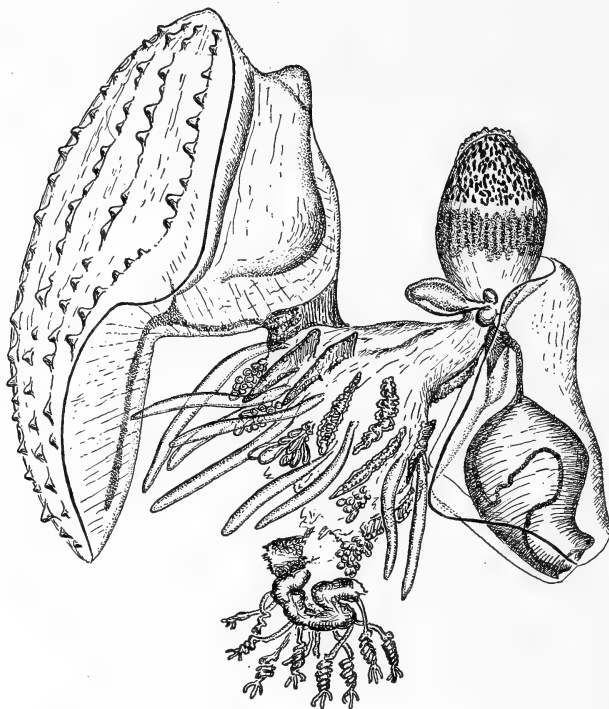


Fig. 217. *Athorybia rosacea*; general view of fragmentary specimen,  $\times 7$ ; from Arcturus Sta. 59. This specimen has lost most of the bracteal attachments, palpons and siphons.

nizable figure dates back to 1776), it has not appeared in any of the recent collections that have added so much to our knowledge of this interesting group. The present series is therefore of interest, especially as it offers an opportunity for comparison with the various older accounts that appeared during the last half of the past century, by K  lliker (1853, p. 24, Taf. 7); Gegenbaur (1860, p. 412, pl. 32, fig. 43, 44 "*Athorybia heliantha*"); Haeckel (1888 a, p. 276, pl. 11, figs. 10-18 "*Athorybia ocellata*"); Chun (1897, p. 49, Taf. 4 "*Athorybia melo*"); and Schneider (1898).

There is no question but that the forms described by K  lliker, Haeckel and Schneider under the names above listed represent a single species identical

with the *Rhizophysa melo* earlier described and illustrated by Quoy & Gaimard (1827), for in addition to the shortened stem, petal-like arrangement of bracts and tricornuate tentilla of the genus, all of them are characterized by bracts not only distinctive in outline, as described below, but longitudinally ribbed on

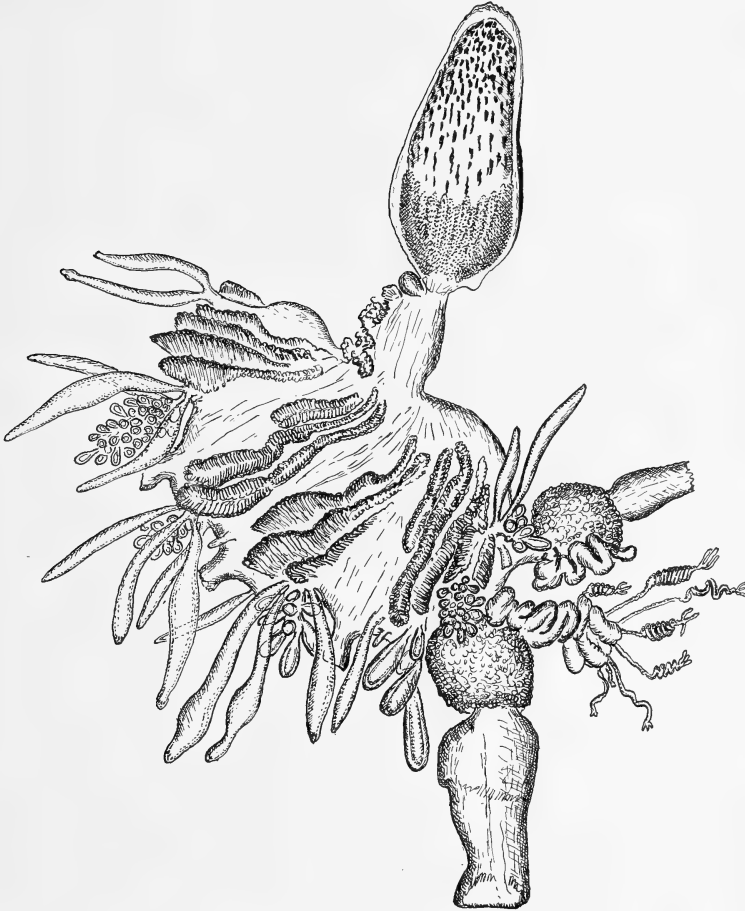


Fig. 218. *Athorybia rosacea*; general view of specimen,  $\times 8$ ; from Arcturus Sta. 74.

the distal surface with series of short conical gelatinous papillae. Unfortunately it will never be possible to settle conclusively whether or not it was this same form that Forskål described and pictured as *Physophora rosacea*, for his figures and account would apply equally to any *Athorybia*. But it will tend towards stability to employ Forskål's name, there being no internal evidence to forbid. Gegenbaur's (1860) *Athorybia heliantha* may be a distinct species, for while

his account agrees in general with those of K  lliker, Haeckel and Schneider, he states that the surfaces of the bracts were not ribbed nor papillose. And as his material was evidently in good condition we cannot suppose that so close and accurate an observer would have overlooked a character as obvious as is the sculpture of the bracts of *A. rosacea*: especially when Gegenbaur especially emphasized this difference between his specimens and K  lliker's. Furthermore Gegenbaur described the bracts as arranged in a spiral, which is not the case in *A. rosacea* (see p. 581 on this point). Gegenbaur identified his *Athorybia* with the *Physophora heliantha* of Quoy & Gaimard (1827), the bracts of which are similarly described and pictured by these French zoologists as smooth, with only "une strie longitudinale dans leur milieu," in contrast to the ribbed bracts of their *A. melo*. But their statement (1827, p. 178) that the stem of their *heliantha* was "susceptible de s'allonger indefiniment" raises the question whether their picture may not have been taken from a much contracted Agalmid of some sort.

The several accounts of *A. rosacea* have given us a good understanding of the general organization of this interesting genus, except as to the arrangement of siphons, palpons and gonodendra on the abbreviated corm, and their number. While the present specimens are too much contracted, and too fragmentary to clear this matter, they allow some additional notes on the individual organs especially welcome in the case of the stem and nectophores. The stem, as Haeckel seems first to have recognized, is separated into two distinct sectors, the upper nectosome, the lower siphosome, just as it is in all the long-stemmed Physophores and in *Physophora* as well. In contracted individuals it is so shortened that the attachments of the bracts are crowded up close against the pneumatophore; the latter may even be drawn downward until it is partially invaginated within the upper part of the stem, as Schneider (1898) found it in the specimens that he sectioned. But in relaxed specimens (formalin preservation is here of great advantage) the nectosome-sector is approximately as long as the siphosome-sector (Figs. 217, 218). And there is a considerable contrast between the two in breadth, the former relatively narrow, the latter expanded in a conical vesicle as Haeckel observed.

All of the *Arcturus* specimens show this distinction into an upper, neck-like and a lower swollen portion, though in most of them the former is more contracted than in the examples illustrated (Figs. 217, 218).

Careful examination of the present material is convincing to the effect that the siphosome-sector (as in all the long-stemmed Physophores, and in *Physophora*) bears only the nectophores—in this case mostly rudimentary. Early accounts to the effect that the bracts are attached immediately below the pneumatophore seem to have been based on contracted material and on the misconception that the muscular lamella that bears the one definitive nectophore, was that of a bract. Even Chun seems to have fallen into this last error, for although he described and beautifully pictured the one large nectophore (1897, pl. 4, fig. 3), the lamella, which was almost certainly its support, is designated on his figure of the contracted corm as the support for a bract (1897, pl. 4, fig. 1).

Every one of the present series shows 1-4 rudimentary nectophore buds just below the pneumatophore, and one muscular lamella, the identity of which is definitely established by the fact that in one example it still bears the larger definitive nectophore (Fig. 217). Otherwise the siphosome is bare of appendages or lamellae. That is to say, there is a definite zone of proliferation for nectophores.

These nectophore buds show various stages in development, from mere knobs to a stage when the bell cavity is visible though the bell is still closed terminally (Fig. 217). The only large bell that is still intact agrees in general with Chun's account and picture. Especially notable is the complex course of the lateral subumbral canals, and the apical prolongation of the gelatinous substance, with stiel-canal of considerable length. There is a minor difference, however, in the fact that the ventral face of the present example is deeply furrowed, with its two wings somewhat clasping the base of the pneumatophore and the siphosome sector of the stem. The muscular lamella bearing this nectophore is well developed; no trace is to be seen of any other such structure that might have borne a second large nectophore.

A question of much interest is whether there is a succession of these large nectophores, or whether only one such definitive bell develops, as is suggested by the fact that the specimens examined by Chun and by me showed only one supporting lamella.

Better material is needed before the details of arrangement of the various organs on the stem can be worked out. The bracts are especially interesting in this connection. As Chun (1897) seems first to have observed, these (like the nectophores) are borne on strongly contractile muscular lamellae,<sup>16</sup> which have subsequently been described in some detail by Schneider (1898). Several of these lamellae are to be seen on each of the present specimens, though invariably so contracted that they give no indication of the degree to which they are extensible in life. Kölliker (1853, p. 24) describes them as arranged in two or three circles close below the pneumatocyst; Gegenbaur (1860) as surrounding the stem in a double spiral; Haeckel (1888 a) as in three or four circles one above another; Chun (1897) as circling the axis of the stem. According to Schneider (1898) they radiate from one point, which he interpreted as the zone of proliferation for the whole series of bracts.

The *Arcturus* specimens show that no one of these more or less conflicting accounts clearly states the case, for none mentions the fact that the lamellae are arranged in groups, much as they are in *Anthophysa*. In the best-preserved example (Fig. 218) there are at least nine such groups (perhaps more), with 3-4 lamellae in each group, suggesting a total of at least 30 bracts, which corresponds to Kölliker's count of 20-40, Haeckel's of 30-50. The lamellae of each group are crowded close together, contrasting with free belts of considerable width between the groups. The long axes of the individual lamella run meridional to the main axis of the siphosome so that the bracts in life form a corona around the latter. Unfortunately the condition of the material is not good enough to show whether there is one primary zone of proliferation for all the bracts as Schneider believed:

<sup>16</sup> Kölliker (1853) suspected a muscular attachment from his observations that the bracts are mobile.

so far as it goes it suggests the contrary. Thus the largest lamellae are approximately of equal length in each of the groups, while within each group there is a wide variation in length, suggesting that fresh bracts are interpolated all around the siphosome as the colony grows. The fact that the only bract still attached (Fig. 217) though a young one, stand opposite the zone of proliferation for nectophores, is evidence in the same direction. The bracts themselves agree so closely with earlier descriptions and illustrations that no account is needed here. Their most distinctive feature, and one that offers a field-character by which this species may readily be recognized, is the presence of the radial tuberculate ridges already mentioned: in fact there is no danger of confusing the bracts of this species with those of any other Siphonophore with which I am acquainted. In three large bracts, chosen at random, the number of ridges was 9, 9, 8.

The relative size of the tubercles is shown in figure 217. On one bract their number, per ridge, varies from about 6 to about 27. Along some parts of the ridges they have the form of conical papillae, but in other places several, together, form continuous crests.

By earlier accounts there are approximately as many palpons as bracts (14-20 or more according to Kölliker; as many as the bracts according to Haeckel). The *Arcturus* specimens have lost part of the palpons; but enough remain to show that their number approximately equals that of the bracts, for two, three or four are to be seen just distal to each group of bracteal supports (Fig. 218). They thus form a corona surrounding the distal portion of the stem. Each of these groups of palpons (so far as can now be seen) arises from a common stem which, in turn, arises close by or perhaps actually as an outgrowth from the basal part of the trunk of a gonodendron, much as is shown by Huxley (1859, *pl.* 9, *fig.* 12). But the condition of the material makes it impossible to determine whether this is an invariable rule, or whether other palpons are borne on the meridional belts of the stem that alternate with gonodendra and groups of bracts. Some large palpons also arise just distal to (i. e. below) the gonodendra. Schneider (1898) has already recorded the close association of palpons with gonodendra, though by his interpretation the latter arise from the bases of the former. In addition to the large palpons, occasional much smaller ones are scattered over the basal surface of the siphosome. As only one specimen is in good enough condition to show any of these (Fig. 218), I cannot state whether or not they remain permanently small. In the example in question 8-10 are intact, but there may have been more in life.

I can add nothing (except by way of confirmation) to earlier accounts of the structure of the palpons. Their most characteristic feature is the presence of a corona of large nettle cells close to the tip. These are still to be seen in contracted examples, but in most cases have been lost. Haeckel (1888 a) describes a crystalline body (he interpreted it as refractive) as associated with the terminal pigment spot recorded by him and by Chun; but this was not visible on any of the present examples.

The siphons, as earlier students have stated, are of the ordinary Physophorid type, with thick walled basal part. They are much less numerous than the groups of bracts, earlier accounts giving eight as the number. The only

*Arcturus* specimen on which even an approximate count is possible (Fig. 218), bears two intact siphons and the broken bases of at least four others. They alternate radially with the groups of bracteal supports.

The tentilla, described in detail by Haeckel (1888 a) and by Chun (1897), are of the ordinary Agalmid type—tricornate, with involucre. According to Chun, the involucre encloses the entire cnidoband until the latter has developed seven turns; if more turns are formed they project free. I need only add that



Fig. 219. *Athorybia rosacea*; tentillum,  $\times 72$ ; from *Arcturus* Sta. 74.

the involucre is not formed until the spiral coiling of the cnidoband is well advanced (Figs. 219, 220); that the largest number of coils found enclosed in any tentillum, in the present series, was 7–8. In most cases (probably as a result of preservation) the involucre is so strongly contracted as hardly to be recognizable as such (Fig. 220).

As has long been known, *Athorybia* is monoecious. Kölliker (1853) and Haeckel (1888 a) both report two gonodendra, a male and a female, close to the base of each siphon, while Huxley (1859, *pl.* 9, *fig.* 12) shows the male and female gonodendra as arising from a common trunk. In the *Arcturus* specimens the gonodendra alternate, radially, with the siphons, thus standing in the general radii of the groups of bracteal supports.



In only one instance did I find a pair (male and female) still intact. Chun (1897) has given an excellent illustration of the female gonodendron. The single large egg that is developed in each gonophore is plainly visible in the present material; male gonodendra bear few gonophores and agree in general with Haeckel's figure (1888 a, *pl.* 12, *fig.* 18) except that (perhaps owing to the rather poor preservation) I have not been able to detect the ring- and radial-canals.

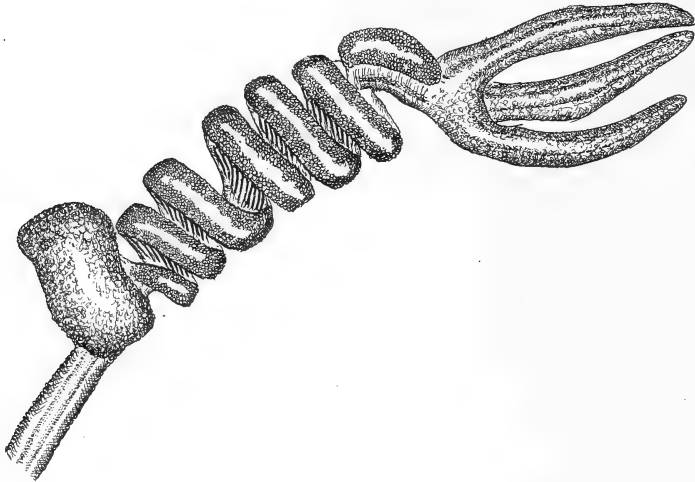


Fig. 220. *Athorybia rosacea*; tentillum with involucre contracted,  $\times 72$ ; from *Arcturus* Sta. 74.

Previous records of *Athorybia* that can be referred with certainty to the species *rosacea* have been confined to the Mediterranean, to the Straits of Gibraltar and to the North Central Atlantic (Latitude  $32-34^{\circ}$  N; Longitude about  $30^{\circ}$  W.). The genus is also recorded from the Indian Ocean and from the Pacific coast of Australia by Huxley (1859) as "*A. rosacea*." But as just remarked (*p.* 0) it is questionable whether his specimens actually belong to this species. The *Arcturus* records are therefore interesting geographically for they extend the known range of *A. rosacea* to the eastern side of the Tropical Pacific, between the Galapagos and Panama. It seems that this Siphonophore, like so many of its confreres, is cosmopolitan in warm seas.

#### Family RHIZOPHYSIDAE Brandt 1835.

*Rhizophysa eysenhardti*, Gegenbaur.

*Rhizophysa eysenhardti*, Gegenbaur, 1860, *p.* 408, *pl.* 31, *figs.* 46-49.  
For synonymy, see Bigelow 1911 a, *p.* 320.

Station 100, surface, two fragments.

Station 102, surface, fragments of three specimens, each with pneumatophore.

These fragmentary *Rhizophysas* are referred to this species because each

still bears filiform tentilla, but none of the complex tentilla characteristic of *R. filiformis*. Being mere fragments they add nothing to previous accounts of the species. The localities of capture are near and in the offing of Bermuda. *R. eyenhardtii* is known to be widespread in the warm belts of all oceans, and has been recorded at various stations in the Tropical Atlantic.

*Rhizophysa*, (sp. ?)

Fragments of *Rhizophysa* without tentilla (hence not identifiable specifically), were taken at Stations 94, 98 and 100.

*Bathypphysa*, (sp. ?)

Expeditions that have done much deep towing, or trawling, have usually picked up examples of this genus, or of its close ally *Pterophysa*, on the wire. But the specimens have invariably been so much damaged that much is still to be learned even as to the chief morphological features of the species concerned. And until good material is obtained, specific and generic relationships can only tentatively be established.

Lens & Van Riemsdijk (1908), who have examined the largest series of the family that has yet been studied, recognize two genera, *Bathypphysa* and *Pterophysa*, separating them by the position of the oldest siphons, which are borne on pedicles in the former, but sessile on the stem in the latter. And their system may be accepted at least provisionally.

The *Arcturus* obtained the following representatives of this group (brought in as usual on the wire):—

Station 28, 500–0 meters, a fragment of stem, with three loose and very much damaged siphons.

Station 38, 545–0 meters, a fragment of stem, about 350 mm. long with pneumatophore, and bases of a number of siphons, the younger of which show traces of wing-like expansion, also two gonodendra.

Station 74, 1145–0 meters, a fragment 47 mm. long with pneumatophore, occasional tentacular bases and one large gonodendron.

In each case the stem is stripped bare of all but the bases of the older siphons and tentacles, though in one a few very young siphons, and several young gonodendra are still attached. They are referred here to *Bathypphysa* because, in each case, either the remaining siphons, or the bases of these organs that are still attached, suggest that they were borne on distinct pedicles: even this, however, is not certain.

Family PORPITIDAE Brandt 1835.

*Porpita pacifica*, Lesson.

*Porpita pacifica*, Lesson, 1826, pl. 7, figs. 3, 3<sup>1</sup>; 1830, p. 2, 59.  
For synonymy, see Bigelow, 1911 a, p. 338.

*Porpita* was taken at the surface at Stations 26, 32, and 33, a total of 11 specimens, ranging in diameter from 2 to 37 mm.

It is now sufficiently established that the several Porpitas that have been named in each of the great oceans represent, in each case, but a single species. But no general agreement has yet been reached as to what relationship the Atlantic representative of the genus bears to those inhabiting the Pacific and Indian Oceans.

The *Porpitas* collected by the *Albatross* in the Eastern Tropical and later in the Northwestern Pacific differed markedly from the Atlantic form, as it has been described, and from specimens of the latter that I have seen, in showing a tuberculate disc; more numerous tentacular cnidocysts; relatively narrower limbus; fewer open stigmata and more complex limbar canals. I therefore referred them to a separate species *P. pacifica* Lesson. And Raj (1927) has used this same name for specimens similarly characterized from the Gulf of Manar between India and Ceylon. Moser (1925), however, from her study of the *Gauss* collection, and of specimens from various localities in the Pacific and Indian Oceans (mostly poorly preserved) believes that the reported differences between the Indo-Pacific "*pacifica*" and the Atlantic "*umbella*" are not specific, but represent either different stages in growth (the *umbella* examined by me were small, the *pacifica* large), or the individual variation to be expected in a cosmopolitan form. Consequently she refers all of them to the earliest named *Porpita*, *P. porpita* which was originally described from the Indian Ocean. As she remarks, the matter cannot be settled for good until some one has the opportunity to compare large series, representing different stages in growth, from the three oceans. Material from the Indian Ocean is especially to be desired from the waters around South Africa, for *Porpita* may be expected to round the Cape of Good Hope from the Indian Ocean into the South Atlantic, in considerable number, at the season (January–March) when the warm Agulhas current reaches its greatest westward extension, and when the surface temperature off Southwestern Africa is highest, (c/f Schott, 1902, pl. 8).

Meantime it is of interest to find the *Arcturus* specimens—small as well as large—agreeing so closely with the *Albatross* series from the same general region as to suggest that this particular form—whether species or variety—is in fact characteristic of the eastern side of the Tropical Pacific. Thus the larger specimens (26 mm. in diameter) all show prominent tubercles on the disc, much as illustrated for still larger *Albatross* specimens (Bigelow 1911 a, pl. 8, fig. 1, 2). In fact they are relatively more prominent in one of 19 mm. than in any of the larger examples, and are to be seen even in a specimen of only 14 mm. In a very young example (2 mm. from Station 33) the disc is smooth; and unfortunately there are no intermediate sizes in the series. Thus it appears that the disc becomes definitely tuberculate in this form by the time a diameter of 12–14 mm. is reached. The *umbella* of this size that I have seen show no definite tubercles—but show radial ridges much more prominently than do any of the *pacifica* yet studied.

The *Arcturus* specimens have somewhat fewer stalked cnidocyst-clusters on the tentacles than the *Albatross* series, but a considerably larger number of these structures than have been recorded for *Porpitas* from the Atlantic (*umbella*). Thus the average number per row, on five tentacles each, in three specimens from Japan, 25–40 mm. in diameter, was 29, 17, 17. In the largest specimens from the *Albatross* collection from the Eastern Tropical Pacific there were from 25–29 per tentacle in the long rows, 11–14 in the short. In five *Albatross* specimens from the same general region, 32–36 mm. in diameter

(five tentacles examined in each), the numbers are 19–28 in the long rows, 8–15 in the short, averaging respectively 24, 10, 11, while in one example of 23 mm. the average is nearly as great, namely 22, 10, 10.

As the maximum number of tentacular nematocyst-clusters so far reported for *Porpitas* from the Atlantic is only 9–12 in the long, 6–8 in the short rows, it seems that these organs average considerably more numerous even on small Pacific specimens. But the discontinuity in this respect is not as wide as the *Albatross* collections suggested, and examination of larger series, from other localities may show an unbroken gradation between the extremes. Furthermore, new nematocyst-clusters may be interpolated at any stage in growth, for in several instances small (i. e. young) ones were seen between the larger.

The *Arcturus*, like the *Albatross* specimens also show fewer open stigmata than the Atlantic examples I have examined. And since this applies to three examples only 14–19 mm. in diameter, the difference can not be credited to different stages in growth, though it may to individual (or to swarm) variation. This statement also applies to the difference between Atlantic and Pacific *Porpitas*, with respect to the relative breadth of the limbus. Moser (1925) has pointed out that my photographs showing this difference (1911 a, *pl.* 28, *figs.* 2, 13), were not strictly comparable, the Pacific specimen being considerably larger than the Atlantic. It is therefore fortunate that the present series contains specimens of about the same size as the latter (20 mm.). On all of these the limbus is relatively only about half as broad as in the Atlantic specimen in question, occupying 5–6 per cent of the total diameter, as against about 11 per cent of the diameter. Final decision as to the meaning of this apparent discontinuity must rest on the examination of larger series.

*Arcturus* like *Albatross* specimens also show a more complex anastomosis and branching of the limbar canals (primarily radial arrangement entirely obscured) than any Atlantic specimen I have seen.

Until the relationships of the three *Porpitas* can be definitely established, nothing is to be gained by suppressing the name *pacifica*. But as Moser clearly points out, if the forms are finally united, the name first given to the *Porpita* of the Indian Ocean (*P. porpita*) takes precedence.

*P. pacifica* has already been taken by the *Albatross* in the general region (Panama-Galapagos) covered by the *Arcturus* records, at times in swarms. Evidently it is as characteristic an inhabitant of the Eastern Tropical Pacific as its relative *P. umbella* is of the corresponding thermal zone in the Atlantic.

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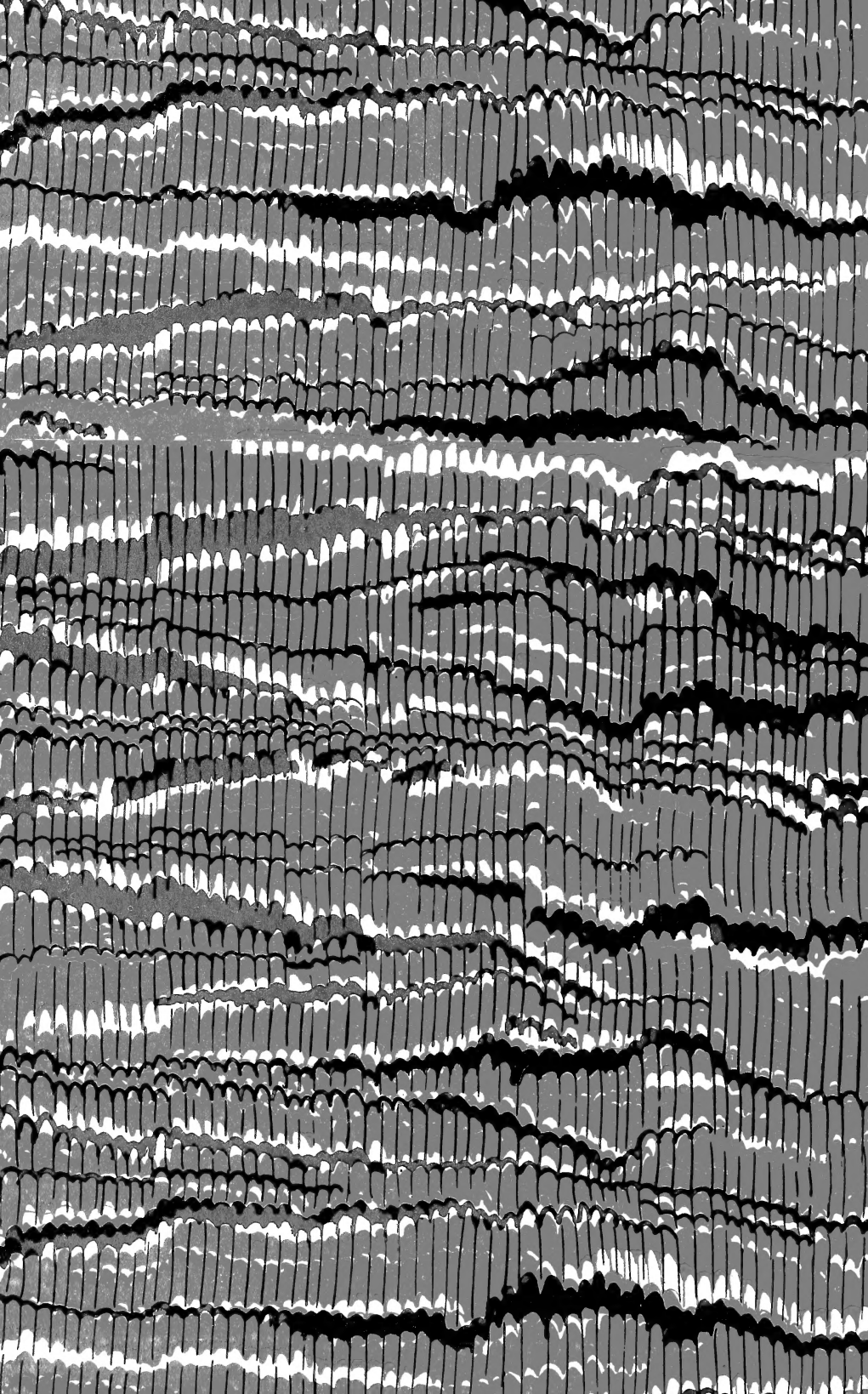


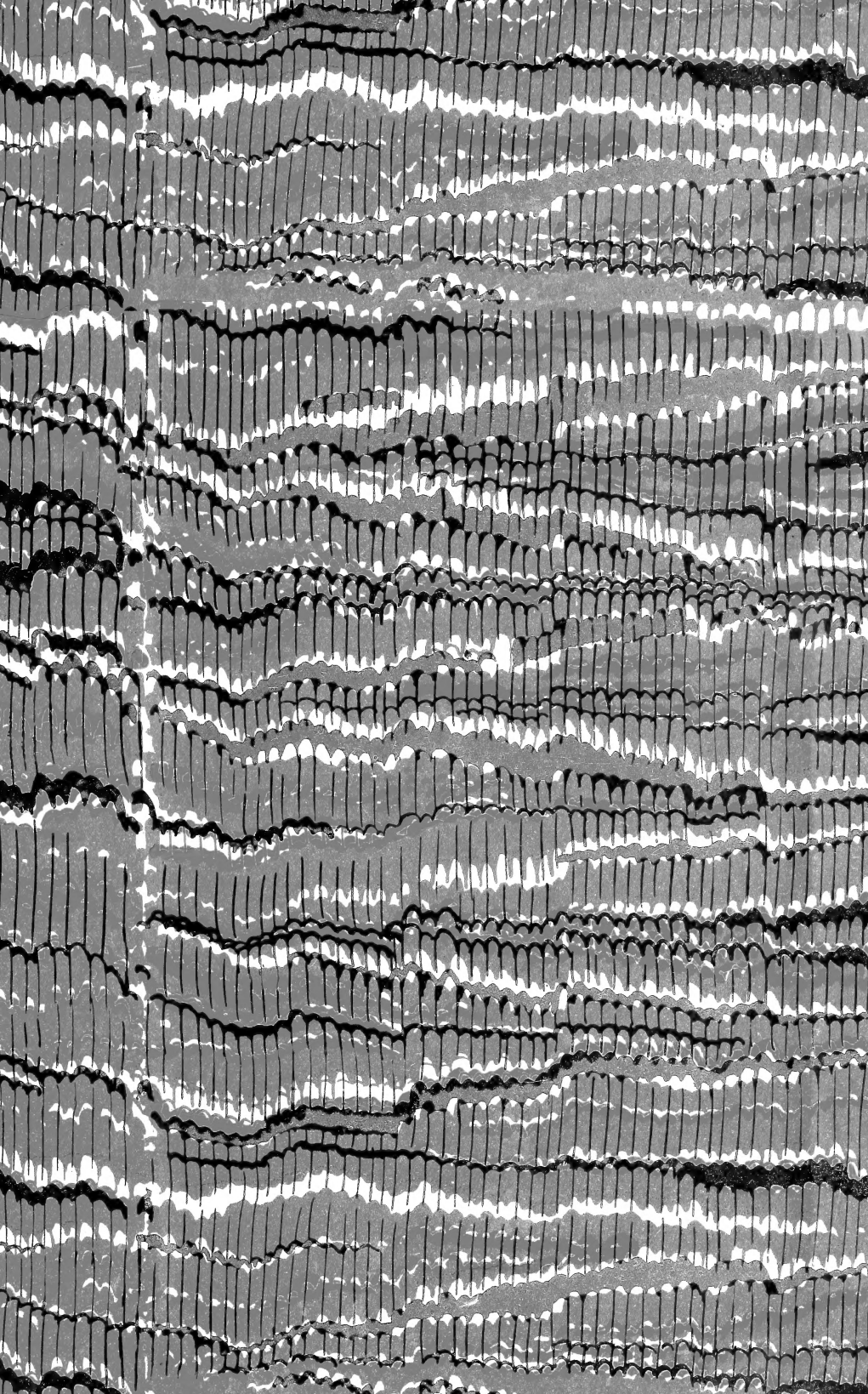












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